GUIDE TO THE STUDY

OF

ANIMAL ECOLOGY

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Fig. 1. — Oyster Bank in South Carolina. Showing colonies of "coon" oysters growing in area between tides. Consult Möbius, Dean, and Grave for the ecological conditions of the animals on oyster banks. This is a representative animal community. Photo. by B. Dean, loaned by U. S. Bureau of Fisheries.

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BY

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PREFACE

During the past ten years the writer has been trying to find some consistent and satisfactory working plan for handling the almost bewildering number of facts, of ecological significance, which have been accumulating in the literature of zoölogy, biology, and the allied sciences. This book is the outgrowth of the effort as it has developed in the study and teaching of animal ecology. I have not attempted to make this an exhaustive treatment of the subject, but rather to indicate briefly some of its general bearings and a method of approach. I have tried to keep in mind the needs of the beginner in ecology.

An ecological point of view is described more fully than the other subjects discussed, so that the student may see the need of familiarity with those tests or criteria by means of which he may be able to determine for himself ecological relations and the validity of ecological studies. The other phases are treated less fully in the discussions and with more detail bibliographically so that this may be a useful source book. The geographical (in the ordinary sense of the word) aspect has been deliberately omitted. The references should be looked upon from the standpoint presented in the general portions of this book, and if the facts and inferences aid in the interpretation of the relations which exist

between animals and the sum total of their environments, one may fairly consider that they are of ecological worth.

In the arrangement of the references I have tried to group related papers, but many defy any single system. Some of the publications deserve to be in several lists, but little duplication has been made, as this would unduly prolong the lists. The annotations will supplement the titles and their grouping in indicating the contents and importance of the papers for our purpose. It has often been difficult to select from several almost equally valuable and useful papers. Others with different interests, aims, and experience would doubtless make a different choice. It will therefore be a favor, if those who use this handbook and feel that important papers have been excluded, will communicate this fact to the author.

This book is not intended as a treatise on the science of ecology; its aim is primarily educational. This is the justification, if any were necessary, for placing emphasis upon the point of view and the importance of an understanding of explanatory processes and of the methods of scientific investigation. Any adequate treatment of this subject would exceed the space of this volume and it is reserved for future elaboration.

At present ecology is a science with its facts out of all proportion to their organization or integration. There is thus an immediate need of integration, and this above all requires a clear conception of the sci-

entific method as a tool, and independent thinking as well. The fact that scientific work progresses more rapidly when consciously pursued than otherwise should serve as ample justification for this emphasis.

A word of explanation is desirable to explain certain features of this volume. It is the outcome of coöperative work on the part of the Illinois State Laboratory of Natural History and certain members of the Ecological Survey Committee of the Illinois Academy of Science, Professors E. N. Transeau and T. L. Hankinson. A local ecological study was made, as a piece of coöperative work, and directions for study were to be an introductory section of my part of this report. But as this part grew on my hands, with the permission of Professor S. A. Forbes, Director of the Illinois State Laboratory of Natural History, I decided to publish it separately. This part was written two years and a half ago, and when separate publication was decided upon, additional references to the literature were added to bring it to date. These circumstances explain the emphasis placed upon ecological surveying and also the brevity of treatment of other aspects.

Further, I am indebted to Professor Forbes for reading the manuscript and for valuable criticisms, and likewise, for similar assistance, to my wife, Alice Norton Adams. Skillful help on the proof and index has been given by Miss Marion E. Sparks.

CHARLES C. ADAMS.

URBANA, ILL., U.S.A.,
June 9, 1913.

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RELATION OF ECOLOGY TO BIOLOGY

"I shall try to show that life is response to the order of nature. . . . But if it be admitted, it follows that biology is the study of response, and that the study of that order of nature to which response is made is as well within its province as the study of the living organism which responds, for all the knowledge we can get of both these aspects of nature is needed as a preparation for the study of that relation between them which constitutes life."

"To study life we must consider three things:

first, the orderly sequence of external nature;

second, the living organism and the changes which take place in it; and,

third, that continuous adjustment between the two sets of phenomena which constitutes life."

"The physical sciences deal with the external world, and in the laboratory we study the structure and activities of organisms by very similar methods; but if we stop there, neglecting the relation of the living being to its environment, our study is not biology or the science of life."

W. K. BROOKS.

ANIMAL ECOLOGY

I. AIM, CONTENT, AND POINT OF VIEW

Ecology has no aim, but ecologists have. The problems of the ecologist are not fundamentally different from those of any other kind of naturalist. The superficial differences in aim are due to the different points of view, or methods of approach, rather than to any essential difference in the character of the problems.

The essentially biological core of ecology may be best shown by considering the relation which this science bears to other branches of biology, a relation which has been admirably expressed by the eminent physiologist, Burdon-Sanderson ('94, pp. 438–439), as follows:

"Now the first thing that strikes us in beginning to think about the activities of an organism is that they are naturally distinguishable into two kinds, according as we consider the action of the whole organism in its relation to the external world or to other organisms, or the action of the parts or organs in their relation to each other. The distinction to which we are thus led between the *internal* and *external* relation of plants and animals has of course always existed, but has only lately come into such

prominence that it divides biologists more or less completely into two camps — on the one hand those who make it their aim to investigate the actions of the organism and its parts by the accepted methods of physics and chemistry, carrying this investigation as far as the conditions under which each process manifests itself will permit; on the other, those who interest themselves rather in considering the place which each organism occupies, and the part which it plays in the economy of nature. It is apparent that the two lines of inquiry, although they equally relate to what the organism *does*, rather than to what it *is*, and therefore both have equal right to be included in the one great science of life, or biology, yet lead in directions which are scarcely even parallel. So marked, indeed, is the distinction, that Professor Haeckel some twenty years ago proposed to separate the study of organisms with reference to their place in nature under the designation of 'œcology,' defining it as comprising 'the relations of the animal to its organic as well as to its inorganic environment, particularly its friendly or hostile relations to those animals or plants with which it comes into direct contact.' [1] Whether this term expresses it or not, the distinction is a fundamental one. Whether with the œcologist we regard the organism in relation to the world, or with the physiologist as a wonderful

[1] These he identifies with "those complicated mutual relations which Darwin designates as conditions of the struggle for existence." Along with chorology — the distribution of animals — œcology constitutes what he calls *Relations-physiologie*. Haeckel, "Entwickelungsgang u. Aufgaben der Zoologie," Jenaische Zeitschr., 1869, Vol. V, p. 353.

complex of vital energies, the two branches have this in common, that both studies fix their attention, not on stuffed animals, butterflies in cases, or even microscopical sections of the animal or plant body — all of which relate to the framework of life — but on life itself."

The quotations from Brooks, on a preceding page, show even more explicitly the intimate relation which exists between biology and ecology. At first glance they may seem to prove almost too much — that biology and ecology are synonymous. They show at least that ecology is concerned with fundamental biological problems — the responses of organisms to their complete environments.

The relations which different branches of ecology bear to one another may be discussed under three headings, individual, aggregate, and associational ecology. These phases are superficially so distinct that students of one branch may be almost unaware of the existence of the coördinate branches and may not realize that each is a part of the larger unit.

Individual Ecology. — The study of individual ecology is the investigation of the development (*process* of formation) of the structure, function, and behavior of a given individual or kind of animal from the standpoint of its relations and responses to the complete environment. All ecologically significant facts should be considered. Such a study may be devoted to an animal, as, for example, a bumblebee, a crawfish, or a garter snake, and may be limited to a single habitat or locality, or extended

throughout the entire geographic range of an animal. From this standpoint the individual studied becomes the hub of the microcosm, from which all relations and responses radiate. Most of the physiological studies of ecological bearing and many investigations of animal behavior have been made from this viewpoint. The organism is thus considered as an agent which, transforming and utilizing substance and energy, produces a varied number of physiological conditions and forms of activity, which in turn furnish the basis for the constant process of response between the organism and its environment.

Aggregate Ecology. — The study of aggregate ecology is the investigation of the ecological development, relations, and responses of animals based upon hereditary or taxonomic units, as in a family community, or in genera, families, orders, etc. These groups or aggregates are made the basis for the ecologic study, as a hive of bees, birds, dragon flies (Odonata), the genus *Bombus*. From this approach the activities and responses of the group are traced throughout all environments and associations within the area studied, or throughout the world, and its responses and adjustments to the whole environment receive primary attention. The hereditary or taxonomic unit is here the hub of the microcosm. Perhaps most of the contributions to ecology by the taxonomists are made from this standpoint. Here also the aggregate is considered as an agent or entity which produces many kinds of activities and adjustments to the environment.

Associational Ecology. — Associational ecology is devoted to the investigation of the development, interrelations, and responses of animals which are grouped or associated in the same habitats and environments. In this case the associates in a given association and habitat are considered as a unit, whose activities and interrelations and responses are investigated in the same manner as if it were a single animal. The interactions among members of an association are to be compared to the similar relations existing between the different cells, organs, or activities of a single individual. Such groupings have a composition which has developed into an arrangement, or "spacing," of individuals within it, and which produces a particular plan or pattern, as a result of the innumerable responsive activities on the part of the individuals which live together. For example, when the animals living in a small brook, the littoral zone of a lake, in a colony of breeding gulls, or on the floor of a forest, are treated as a unit, the entire history of the animals in the habitat is considered as a response to the conditions of life.

In this form of study the association becomes the center of all radiating relations and responses. Such an association is an agent which transforms substance and energy, producing varied physiological conditions and responses in the continuous process of adjustment "which constitutes life." The physiological needs and states of an association have as real existence in individual animals as have

similar needs in the cell or cells which compose the animal body. The mere statement of the facts of such relations is enough to make valid such a comparison.

For the associational aspect of ecology the German naturalist, Möbius, proposed in 1877 the term "biocœnosis." The meaning of this he expressed very clearly and concisely, and on account of its relatively obscure publication, in a paper devoted to oyster culture, it has not gained the circulation among zoölogists which its importance merits. His statement (Möbius, '83, p. 723) is as follows:

"Every oyster-bed is thus, to a certain degree, a community of living beings, a collection of species, and a massing of individuals, which find here everything necessary for their growth and continuance, such as suitable soil, sufficient food, the requisite percentage of salt, and a temperature favorable to their development. Each species which lives here is represented by the greatest number of individuals which can grow to maturity subject to the conditions which surround them, for among all species the number of individuals which arrive at maturity at each breeding period is much smaller than the number of germs produced at that time. The total number of mature individuals of all the species living together in any region is the sum of the survivors of all the germs which have been produced at all past breeding or brood periods; and this sum of matured germs represents a certain quantum of life which enters into a certain number of individuals, and which,

Fig. 2.—Struggle for Existence on a Clam Flat. Showing the overcrowded condition of a colony of Soft Clams (*Mya arenaria*) on Rowley Reef, Massachusetts. The pits mark the positions of the living clams. Photo. by Belding, loaned by Mass. Comms. Fisheries and Game.

as does all life, gains permanence by means of transmission. Science possesses, as yet, no word by which such a community of living beings may be designated; no word for a community where the sum of species and individuals, beings mutually limited and selected under the average external conditions of life, have, by means of transmission, continued in possession of a certain definite territory. I propose the word *Biocœnosis*[1] for such a community. Any change in any of the relative factors of a biocönose produces changes in other factors of the same. If, at any time, one of the external conditions of life should deviate for a long time from its ordinary mean, the entire biocönose, or community, would be transformed. It would also be transformed, if the number of individuals of a particular species increased or diminished through the instrumentality of man, or if one species entirely disappeared from, or a new species entered into, the community." (See Figure 1).

The three methods of approach to ecological study are not so distinct as they appear at first thought. With perfecting knowledge the network of interrelations increases and the paths converge. Then also the study of the individual behavior of "social" animals, as ants, white ants, bees, or birds which live and breed in colonies, shows transitional stages from the individual unit to that of the family, the colony, and on to the association. Yet the advantage of each point of view should be recognized as an aid in the analysis and synthesis of any problem.

[1] From *βίος*, life, and *κοινόειν*, to have something in common.

Some students feel that the study of individual ecology should precede that of the associational. Within certain limits this is true, but if our general knowledge of biology had waited for the perfection of our knowledge of the individual cells of animals, the results would have been disastrous to all concerned. Even now our knowledge of these subjects is very incomplete. For similar reasons there should be no delay in studying animal aggregates and associations.

A combination of ecological and taxonomic study generally appeals most strongly to those students who have made a specialty of some group of animals. They are familiar with certain forms, have some confidence in taxonomic methods, and frequently have given some attention to habits, life histories, and to collecting. To those who like the descriptive aspect of taxonomy, ecological studies also offer a new field for further description and classification. At present perhaps the majority of ecological students have entered the subject through taxonomy. It is the almost universal verdict of such students that it has required much effort on their part to make the change in the point of view. Such a change cannot be made by a simple resolve, but requires a modification of the habits of the mind, which will be attended by a distinct consciousness of effort. As in other habits, reversion to the older attitude of mind is very easy. This change in point of view is a problem in habit formation, a study of the mental behavior of the ecologist, which is in reality the main topic

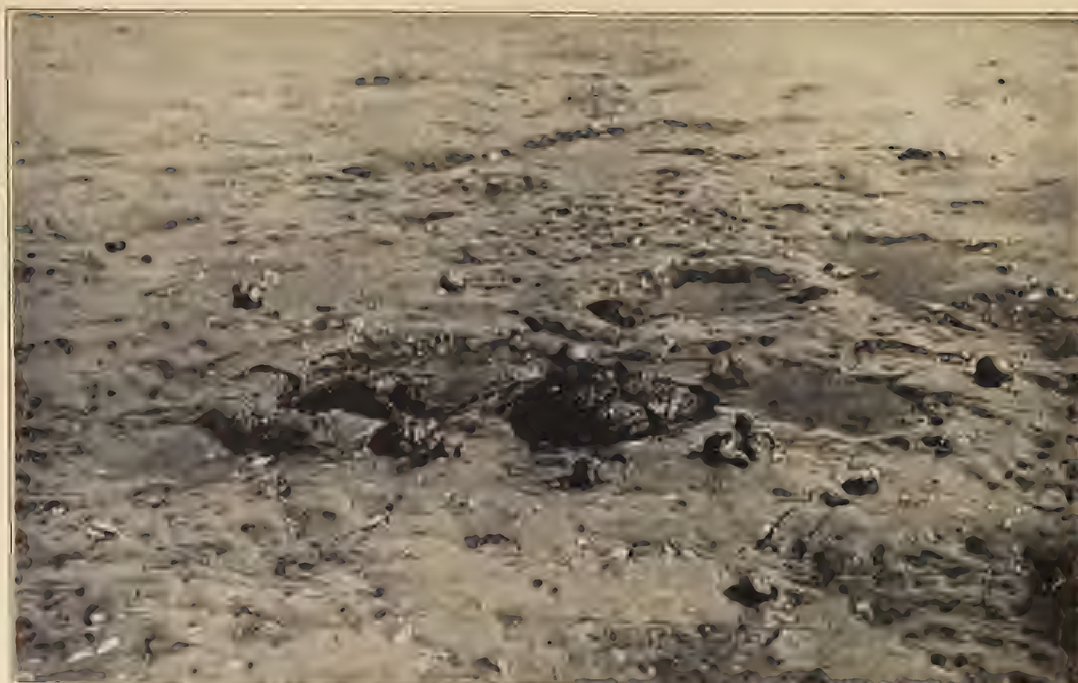

Fig. 3.—Struggle for Existence on a Clam Flat. Showing the destruction of Soft Clams by Horseshoe Crabs (*Limulus*) and Cockles (*Lunatia*), Rowley Reef, Massachusetts. Photo. by Belding, loaned by Mass. Comms. Fisheries and Game.

thus far discussed. One may attempt to make such a change and find that he does not have sufficient modifiability to make it permanent, so that it is only for the moment, during actual collision with some stubborn fact, that he is able to realize ecological relations and an ecological point of view.

To the physiologist, however, individual ecology tends to appeal most strongly, and he, perhaps on account of the preponderance of analytical methods in his work, feels that this is the safest and most important aspect. This statement is perhaps also true of most students of animal behavior. This is largely due to the great present need of analytical methods in these lines, and perhaps indicates a stage in the development of their science rather than a permanent condition. Later a synthetic development will probably become more prominent, and with it will come a change in estimating relative values. Generally physiologists allow for a greater influence of the environment than do many other students. They are impressed with the dependence of organisms upon their environment, and the study of their reactions only reinforces this conception.

The ecologist who studies the responses of animals cannot help being impressed with the processes of adjustment, and with adaptation as a *process*. It is adaptation as a process, rather than as a product, which perhaps interests him most, and emphasis needs to be placed upon this distinction. The problem of adaptation as a process may be a different and separate one from that of evolution, but indi-

vidual animals must have shown adjustive adaptation, or there could have been no perpetuation to continue the struggle of adjustment. Ecological problems are likely to raise a question as to the relative importance of adaptation and evolution — if they are separate problems. The present generation has perhaps been more deeply impressed by evolution as a process, than by adaptation as a process.

The ecology of living animals is only the latest chapter in the volume on this subject; the preceding chapters will contain a history of the indefinitely long series of ecological responses which have taken place in the geologic past. Here is where the ecologist and paleontologist and geologist find common ground. The ecology of living animals must furnish us with whatever firm basis we have for the interpretation of the conditions of life in the past, upon which the paleontologist, stratigrapher, or paleogeographer must depend, at least in part, for his interpretations.

With still another training and interest, as in the case of those especially interested in human affairs, such as the sociologist, the physician, the sanitary expert, and the agriculturist, we may ultimately expect a greater appreciation for the associational aspect because of the social or associational character of human society. The associational is the phase of animal activity which may be considered as the form of animal behavior which has developed into the human social relations. It is a response to the complete organic and inorganic environment.

It is rather natural that in a relatively newly recognized subject like ecology this human aspect has not been very fully discussed. For practical reasons the ecology of man has been developed largely independent of that of animals; just as human physiology and psychology have been developed relatively independent of comparative or general physiological psychology. To the mutual advantage of these subjects they are now rapidly converging, and we may anticipate a similar relation between general animal ecology and the ecology of man. In a general treatise on animal ecology the human phase should not receive undue emphasis any more than it should in a general physiology of animals or in a comparative psychology. But, nevertheless, the relationships of man and his animal associates (slaves, domestic animals, rats, mice, parasites, etc.) form as truly an animal association as do those of the animals which live associated in some forest glade; and in all probability, before any approximately complete understanding can be had of the human associations, their roots and principles of activity must be known and understood in the less aristocratic portion of his animal relatives.

The recognition of the associational aspect of ecology, as well as that human ecology is a part of general animal ecology, is of recent origin. This is very well shown in the following quotation from Huxley (1854. On the Educational Value of the Natural History Sciences):

"Biology deals only with living beings as isolated

things — treats only of the life of the individual: but there is a higher division of science still, which considers living beings as aggregates — which deals with the relation of living beings one to another — the science which *observes* men — whose *experiments* are made by nations one upon another, in battlefields — whose *general propositions* are embodied in history, morality, and religion — whose *deductions* lead to our happiness or our misery — and whose *verifications* so often come too late, and serve only

'To point a moral, or adorn a tale' —

I mean the science of Society or *Sociology*."

At a later date (1876. On the Study of Biology) Huxley says: "For whatever view we may entertain about the nature of man, one thing is perfectly certain, that he is a living creature. Hence, if our definition is to be interpreted strictly, we must include man and all his ways and works under the head of Biology; in which case, we should find that psychology, politics, and political economy would be absorbed into the province of Biology. In strict logic no one can object to this course. . . . The real fact is that we biologists are a self-sacrificing people . . . [so that] we feel that we have more than sufficient territory. . . . But I should like you to recollect that that is a sacrifice, and that you should not be surprised if it occasionally happens that you see a biologist apparently trespassing in the region of philosophy or politics; or meddling with human education; because, after all, that is a part of his kingdom which he has only voluntarily forsaken."

Whether sociology is regarded as a response of man to his fellows or to the whole of his environment is inconsequential in its bearing upon whether or not it is ecological. The response of man, as an animal, to a part or the whole of his environment is strictly ecological. Huxley recognized one relation very clearly, and that is that the ecological relations of *individuals* do not currently include the higher synthesis which deals with them as associations, or "aggregates" as he terms them. So far as known to the writer, human activities in general have never been fully and comprehensively oriented from the ecological standpoint, even by the humanitarians themselves, although some important preliminary steps have been taken. It looks as if such a viewpoint might give a new unity to all studies of human relations.

There is still another class of persons, particularly teachers and isolated students, who desire first of all to understand and interpret their own vicinity, and who will inquire which of the three plans their work best fits. If such a one begins with the detailed study of each species, the general survey will not be completed during his lifetime. If he uses the larger taxonomic units, he may survey the field by going over the same ground again and again, with each of the different groups successively in mind, until the entire field has been surveyed. Or, lastly, he may divide the area into associations and study the animals which are found living together, and by studying one association after another he may cover the entire field.

A teacher will find certain important advantages in this plan, and certain disadvantages. One of the most important considerations in its favor is that such a study results in a familiarity with the kinds of animals one actually finds in natural groups, as when his class is on an excursion. The natural history which a farmer, a fisherman, a summer vacationist, or a sportsman acquires is grouped in this same manner. Thus to a large number of people this is the natural method of approach, and is generally of most permanent value, except possibly to some professional teachers or zoölogists. One of its greatest disadvantages is that in most of the literature which one must use, the animals are not grouped in this way, but taxinomically.

The individual, aggregate, and associational methods of study are in themselves subject to diverse angles of approach, and each has its particular advantages and disadvantages. Of the methods of approach mention will be made of three only, the descriptive, the comparative, and the genetic or method of processes. The descriptive method must develop to some degree before the genetic problems can be adequately stated, and the mature development of the genetic may, and generally does, lag far behind that of the descriptive. The reason for this is simple, for it is evident that it is much easier to describe what we see than it is to explain how it originated or its process of development. At present biology as a science is mainly in the descriptive stage, though it is slowly but surely becoming explanatory

and genetic. The developmental or explanatory method is so difficult that every possible expedient — observation, comparison, reflection, experiment, etc. — must be used to secure the proper development of the main phases of ecology. There is a marked tendency in the naturalist to master one system of work, as observation or experiment, and to use it as a tool almost exclusively, turning from one phase of the subject to another, and continuing the use of the same method. This way of working is favorable to a good technique, but its weakness is that it often tends to give its user a feeling of the great superiority and reliability of the result reached by his method, and a correspondingly less appreciative recognition of results secured by other methods. To observe, to experiment, to reflect, to dissect, to stain, and to collect are only partial methods of investigation, and this fact should be realized and be kept in mind when estimating values and planning work.

The aim of the ecologist is professedly genetic or explanatory because it is the study of *responses* to all conditions of the complete environment. But these responses must be described, and the conditions influencing them as well, so that a descriptive aspect is an essential part in all phases of ecology. In the study of the responses of an individual, an order, or an association, pure description of the responses is necessary; but a description which will at once describe and show the working of the processes by which the results were produced, is of quite a different

order. This phase of explanation has been most concisely expressed and applied by the students of the physical sciences, and biologists may profit much from a study of their methods.

When, however, we turn to the viewpoint of the development of the science of ecology as a whole, a symmetrical development of the subject is most desirable. The preponderating influence of any special point of view tends, like dominance in general, to smother or suppress other germinating and competing ideas. The different special interests each have their advantages and disadvantages, as does a general interest. Diversity in students leads to diversity in the development of the subject, and a variety of emotional appeals to the student has its advantages. And just as the special student should devote some attention to the general bearing of his work, so also should the student of the general aspects cultivate some special field of interest.

The preceding discussion of the aims and methods in ecological study has been intended to indicate some of its general bearings, and to give the student some idea of the tests or criteria which may be used to aid in steering his course through the maze of observations which he may make and the opinions which he encounters. It is of equal importance for the student to be able to perceive ecological relations as recorded by others, because one person's experience is so limited compared with the general body of recorded fact and inference. Furthermore, there are also so many degrees and kinds of

work that go by the name ecological, which may or may not be, and so many also which are truly ecological but which do not pass under that name, that it is necessary that the student shall be able to see through its diverse guises and recognize its essential character. Whenever the question arises as to the ecological character of a fact, inference, or conclusion, its ecological validity may be tested in the following way:

Do the facts, inferences, or conclusions show a *response* to the inorganic or organic environment:

1. As an individual of a species or kind of animal?
2. As a group of taxonomically related animals?
3. As an association of interacting animals?

REFERENCES ON THE ECOLOGICAL STANDPOINT

In this I have listed only those papers which have seemed to me particularly significant because of their point of view, regardless of whether or not they are primarily zoölogical or specifically mention ecology.

Brooks, W. K.

1899. The Foundations of Zoölogy. pp. 339. New York.
Introductory, pp. 1–29; Huxley, and the Problem of the Naturalist, pp. 33–46; Nature and Nurture, pp. 49–79.

1906. Heredity and Variation; Logical and Biological. Proc. Amer. Phil. Soc., Vol. XLV, pp. 70–76.
An extremely suggestive paper which should be read by every ecological student.

Ganong, W. F.

1907. The Organization of the Ecological Investigation of the Physiological Life-Histories of Plants. Bot. Gaz., Vol. XLIII, pp. 341–344.

1904. The Cardinal Principles of Ecology. Science, N. S., Vol. XIX, pp. 493–498.

Burdon-Sanderson, J. S.

1894. Biology in Relation to Other Natural Sciences. Smithsonian Report for 1893, pp. 435–463.

Möbius, K.

1877. Die Auster und die Austernwirthschaft. pp. 126. Berlin.

On page 72 he proposes the term "biocœnose" for the group of animals which live together in the same habitat. Not seen by writer.

1883. The Oyster and Oyster-Culture. Rep. U. S. Fish Comm., 1880, Part VIII, pp. 683–751.

Translation of preceding paper. On pp. 721–729 he discusses "An Oyster-Bank as a Biocönose, or a Social Community"; on page 723 he proposes the word "biocœnosis." An illuminating paper.

Dahl, F.

1902. Die Ziele der vergleichenden "Ethologie" (d. i. Biologie im älteren engeren Sinne). Verh. V. Inter. Zool.-Cong. 1901, pp. 296–300.

1908. Grundsätze und Grundbegriffe der biocönotischen Forschung. Zool. Anz., Bd. XXXIII, pp. 349–353.

1898. Experimentell-statistische Ethologie. Verh. der Deutsch. Zool. Gesell. Bd., 1898, pp. 121–131.

1901. Was ist ein Experiment, was Statistik in der Ethologie? Biol. Centralbl., Bd. XXI, pp. 675–681.

Wasmann, E.

1901. Biologie oder Ethologie? Biol. Centralbl., Bd. XXI, pp. 391–400.

Wheeler, W. M.

1902. 'Natural History,' 'Œcology' or 'Ethology'? Science, N. S., Vol. XV, pp. 971–976.

Advocates the use of the term ethology.

St. Hilaire, I. Geoffray.

1859. Histoire Générale des Règnes Organiques, Vol. II. Not seen by writer. Dr. W. M. Wheeler, of Harvard University, has kindly sent me the following note from p. 285. " 'It is to ethology therefore that the fourth part of this work is devoted, to which belongs the study of the relations of organisms within the family and the society in the aggregate and in the community.' In a volume of the same work, page xx, St. Hilaire gives his program and speaks of the general facts belonging to ethological laws. These are defined as 'relating to the instincts, habits and more generally to the external vital manifestations of organisms.' " About the preceding Dr. Wheeler remarks: "You see this covers precisely the field which was a few years later called 'ecology' by Haeckel. Apparently the part of the work in which St. Hilaire wished to give a detailed account of the ethological phenomena of animals was not published. Only three volumes of the work exist. He died November 10, 1861, without having completed the work."

Thus ethology has priority over ecology, but to my mind this fact carries no special weight, particularly since the word has become current in botany. To use a different name for the same subject or process in botany and zoölogy is as undesirable as to use a different term for heredity in plants and in animals.

Lankester, E. R.

1889. Article "Zoölogy." Ency. Britannica, 9th ed. Amer. Reprint. Vol. XXIV, pp. 842, 856.

Lankester defines "Bionomics. — The lore of the farmer, gardener, sportsman, fancier, and field naturalist, including thremmatology, or the science of breeding, and the allied teleology, or science of organic adaptations: exemplified by the patriarch Jacob, the poet Vergil, Sprengel, Kirby and Spence, Wallace, and

Darwin. . . . Buffon (1707–1788) alone among the greater writers of the three past centuries emphasized that view of living things which we call 'bionomics.' Buffon deliberately opposed himself to the mere exposition of the structural resemblances and differences of animals, and, disregarding classification, devoted his treatise on natural history to a consideration of the habits of animals and their adaptations to their surroundings, whilst a special volume was devoted by him to the subject of reproduction. . . . Buffon is the only prominent writer who can be accorded historic rank in this study."

As I have access to but few of Buffon's writings, I quote the above. Bionomics is seen not to be synonymous with ecology, as defined by most students, although it includes much that is ecological. The chaotic and unorganized "lore of the farmer" has no unifying or guiding principles, and although it contains many facts, from which a science may be built, to call it science seems undesirable.

It is of course advantageous in some ways to have agreement as to the limitations of ecology, or any science, but even the more exact sciences seem to fare little better, as is shown by the following statement: "It is not long since I heard a university professor begin a lecture on physics somewhat in this way: 'Physics is the science of matter and energy. This field is so large that it is customary at present to break off the physics of the molecule and its reactions and call it chemistry. Also to put to one side the physics of the heavenly bodies and call this a part of astronomy,' etc." (Strong, Science, N. S., Vol. XXXIV, p. 409, 1911.)

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WHITE, C. A.
1893. The Relation of Biology to Geological Investigation. Ann. Rep. U. S. Nat. Mus. for 1892, pp. 245–368.
This paper and the two following references illustrate the intimate relation of ecology to phases of geology.

GRABAU, A. W.
1899. The Relation of Marine Bionomy to Stratigraphy. Bull. Buffalo Soc. Nat. Sci., Vol. VI, pp. 319–367.

WALTHER, J.
1893–94. Einleitung in die Geologie als historische Wissenschaft. I. Bionomie des Meeres. II. Die Lebensweise der Meeresthiere. III. Lithogenesis der Gegenwart. Jena.
Shows the close relation between ecology and geology. The process standpoint is emphasized and the past is interpreted in terms of processes now in operation.

ADAMS, CHAS. C.
1908. Some of the Advantages of an Ecological Organization of a Natural History Museum. Proc. Amer. Associa. Museums, Vol. I, pp. 170–178.

II. THE VALUE AND METHOD OF ECOLOGICAL SURVEYS

"I cannot too strongly emphasize the fact . . . that a comprehensive survey of our entire natural history is absolutely essential to a good *working knowledge* of those parts of it which chiefly attract popular attention, — that is, its edible fishes, its injurious and beneficial insects, and its parasitic plants. Such a survey, however, should not stop with a study of the dead forms of nature, ending in mere lists and descriptions. To have an *applicable* value, it must treat the life of the region as an organic unit, must study it *in action*, and direct principal attention to the laws of its activity." — S. A. Forbes. 1883.

Natural history surveys have come down to us from the early days of zoölogy. These surveys have been of many kinds and have ranged from the adventurous accounts of early and daring explorers to those of such naturalists as Belt, Bates, Wallace, and Darwin, onward to the voluminous accounts of the "Biologia Centrali-Americana," and in the *Challenger* reports. These surveys have contributed greatly to our knowledge of the fundamental facts of zoölogy and to the training of naturalists.

The most frequent form of survey is that carried on along the lines which most nearly approach individual and aggregate ecology. Most of such surveys give only slight attention to the *responsive relation*, or only to its most general aspects. Surveys

of the usual character are of great importance, and with students of taxonomic training and interests only, this form of survey occurs very naturally. Most of the governmental and state surveys and museum expeditions are developed along these lines. The frequency with which such methods are used in surveys, which are expected to produce economic results, indicates that these methods are generally considered the most satisfactory. The exceptions to this rule are mainly surveys of fresh and salt waters, and are related in some way to aquatic resources. Except when detailed individual studies of certain species or some special subject has been made, the usual form of the reports of such surveys is the annotated list. It is rarely that even brief chapters discuss the groupings of the animals as they are found associated in nature. These statements show that, judging from the past, the methods currently used cannot be depended upon for a rapid and symmetrical development of ecology, or for the best development of ecological surveys. These must be developed in a more direct and deliberate manner, by carefully planned and executed ecological investigations. It is desirable also that ecological surveys should be conducted along some one of the three main avenues of approach, individual, aggregate, and associational, in order that the science may develop symmetrically. The following are some of the reasons which may be mentioned in favor of such surveys:

As a record of the associations, their interrelations

and responses to their environment — before they have become too much changed or exterminated. This is a duty to future naturalists and to future science. The animal remains in themselves are only a very incomplete record; their activities and environments are an essential part of the animals and should also be preserved.

The study of original conditions is a simpler problem than after interference by man, but excessive modifications result in the simplicity due to annihilation and a corresponding imperfection of knowledge. The value of a knowledge of original conditions tends to increase with time, and will aid much in future interpretations when there is still more disturbance. Thus an important perspective may be developed which will aid in estimating relative values. At the present time the loss of records of original conditions is only beginning to be felt. The possibility of making certain records will vanish with each generation. It is not even desirable to *preserve all*, but it is evident that many ecological records should be preserved.

As the importance of ecological studies, in natural environments, comes to be more generally recognized the serious encroachments of civilization upon habitats and associations is enforced upon us. Not only are the descriptions of these associations very few in number, but the interrelations of the animals in them are even less known, and the chances of preserving adequate records before their complete extinction are becoming fewer every year. Without

the least disparagement of other lines of work, one can but wonder if the naturalists of the future will commend our foresight in studying with such great diligence certain aspects of biology which might be very well delayed, while ephemeral and vanishing records are allowed to be obliterated without the least concern. These changes are generally greatest where civilized man is most dominant, and in progressive attenuations, zones, or strips, the degree of change produced by him radiates. Ecology has developed only at a late stage in civilization, after much of the environment has undergone great changes, so that in order to study the original conditions, which are of such great historic and genetic significance, he must make long journeys, or invade the swamps or sterile uplands which man has not yet been able to reduce to the average conditions best suited to his needs. This state of affairs is one which, at times, makes him thankful that there are conditions which, for the present at least, man cannot cultivate and utterly change and mutilate. Some appear to think that an interest in such original conditions is of no particular scientific value, or is largely one of sentiment; still others, that such studies have no practical value. But if we come to consider that the original primeval conditions give us our best conception of the *normal processes of nature* and are comparable to the normal health of an organism, it puts the subject in another light. A pathological condition is, of course, a state in a natural process, as is also any disturbance

of the normal order of nature by man, and each should be studied scientifically. But the science of pathology has developed best as a study of the disturbances of normal processes and is interpreted primarily in terms of the normal; and the artificial should be similarly interpreted — the natural being the basis to which all standards must be referred. A comparison may also profitably be made between natural conditions and the physiological and vital optima of organisms and to the responses which are made with departures from such conditions. Similar comparisons should be made in the study of the responses of aggregations and associations in natural environments and departures from them. No matter how much we learn, the normal must remain as the ideal, and all departures from and disturbances of such conditions must be interpreted in terms of this fundamental unit.

To study disturbed, artificial, and "pathological" conditions, without an adequate knowledge of the normal and original conditions of both the organisms and the environment, is an attempt to interpret the abnormal and artificial in terms of itself, rather than in terms of the normal. If, however, the normal is no longer preserved, then its nearest approach should be studied, but with all the more care and caution. With a proper understanding of the normal, the disturbances made by man will be capable of *interpretation in an orderly sequence strictly comparable to that found in the original and natural conditions.* The cutting down and washing of the

lands, the draining and filling of depressions, the flooding of the lands, the destruction (or succession) of plant and animal associations (including crop rotation), are processes brought about or practiced by other organisms or animal agencies. An ecological standpoint gives us a consistent, comprehensive orientation of all these natural and "artificial" activities and processes, and shows the unity in all organic responses to the environment. Man's influence in the main consists of hastening or retarding "natural processes."

Naturalists have for a long time spoken of the "balance of nature" and of the all-pervading influence of any serious disturbance of it. This balance is, of course, only a relative condition, and not absolutely fixed. It swings from one side, then back, sometimes showing considerable amplitude in its swing, then again its moves are very slight, mere tremblings, as it were. But now and then some local catastrophic event occurs which overturns everything, as when a volcano becomes active, or some dominant association takes possession of the field, — as in the case of man, — and a new order is initiated and a new balance is developed. The mongoose in Jamaica, our English sparrow, and rabbits in Australia are the classic examples of the overturning of the local order of nature by the agency of other organisms. Obviously this balance is not a condition limited to any particular locality or group of organisms. Balance is very generally conceded to be of fundamental importance in the study of any

species or group of organisms, if its place in the economy of nature is understood. A vast number of the problems of the economic zoölogist are thus problems, not so much of individual or aggregate ecology, but ones in which the balance of the whole local biotic *association* is concerned.

This was the fact pointed out by Möbius when he studied the oyster and came to see that it must be studied not in isolation but as a member of a community, association of animals, or a biocœnosis, as he called these interrelated organisms. These facts are mentioned, as examples from a vast number that are recorded, to show that our applied or economic zoölogy and entomology are *fundamentally more closely related to associational ecology* than to any other phase of zoölogy, and to suggest that it would be to the great advantage of the students of such problems if they clearly understood this relation. This is also an argument for the ecological organization of a vast number of natural history surveys, because the associational grouping of observations and responses gives the most intimate knowledge of the life of animals in the network of their environmental relations.

In addition to the balance of nature which is found within the small associational units there are the larger ones of considerable geographic extent, which the students of faunal or floral problems frequently call zones or distinct regions. Some of these are distinct ecological units, whose *dynamic status* should be determined, so that we may know and

understand whether it is in a condition of stress, a process of adjustment, or one of relative equilibrium or balance. Under present conditions in what direction does it tend to move? At what rate? The non-ecological surveys have not put these questions or worked deliberately toward a goal which will answer them. For any comprehensive study of this character we need to have determined what may be considered as a *biotic base*, optimum, or balance, toward which relations under given conditions tend, and at which an equilibrium will become established (The Auk, 1908, Vol. XXV, p. 125). Such facts underlie all of the problems involved in the interpretation of climax biotic associations, and their application by man. Cook (1909, Bull. 145, Bur. Plant Industry, U. S. Dept. Agriculture, pp. 7, 8) has expressed similar relations as follows: "Unless we can form a definite idea of the original conditions we cannot expect to judge of their influence on primitive man, nor can we determine what effects man has had upon the vegetation and other natural conditions. We need what might be called a bionomic base line, an idea of the conditions which existed before man came upon the scene, the conditions which would again supervene if the human inhabitants were withdrawn."

It is perhaps significant that the genetic or successional relations of habitats and associations, as contrasted with their descriptive classification, both in plants and animals, have in the past been developed, not by the ecological students who live and work among

conditions greatly modified by man, as in parts of Europe, but in the newer, less modified America. In this respect a parallel exists to the development of our knowledge and the process and genetic interpretation of topography, which has also developed more rapidly in America than elsewhere. The process and genetic method which has developed in this physical science has now spread to the biological sciences and has found a fertile soil there for development on account of the *relatively* undisturbed biotic conditions which still persist in certain areas.

In this connection it may be worth while to indicate some of the ecological disadvantages under which the non-ecological surveys are carried on. As a rule, such surveys feel no strong obligation to record fully the conditions of the environment, or its developmental processes. The environment is considered as static, and not as a changing medium; it has no past or future, it has merely horizontal extension. The problem as to its *dynamic status*, whether in a condition of stress, in the process of adjustment, or in relative equilibrium, is not raised, or if it should be, it could not be handled. The student eager for new and little-known species is not the one to study such relations, at least, as a rule, this has not been his practice. So long as the success of a day's work is measured by the length of the list of novelties secured, rather than by the quality and quantity of ecological relations discovered, such students and surveys will not contribute greatly to our knowledge of the economy of nature in the regions surveyed.

At the present time it is very difficult to secure trained men to do ecological surveying. Even a superficial examination of this paper should show that familiarity with ecologic methods and results is not one to be acquired offhand, but a knowledge which requires considerable special training; not only as much as is usually required for other kinds of zoölogical work, but generally more, because of its synthetic relational tendency which requires a broad knowledge as well as some special knowledge in several lines of biology and the allied sciences. Conventionally considered, a properly equipped physiologist must have a working knowledge of certain phases of modern physics and chemistry in addition to his grounding in biology. A properly trained anatomist should have a knowledge of physiological and developmental processes, or his anatomy is purely descriptive and static. A student of general zoölogy should be grounded not only in physiological and developmental processes, but also in the relations of the organisms to their complete environment. The ecologist requires also the grounding in physiological, developmental, and ecological processes of adjustment, but as well he must understand the processes by which the vegetation and the physical environment have been and are being developed and their method of mutual interrelations and adjustment. It is difficult for some students to develop the ecological phases in the field. There are many disadvantages to be overcome. The difficulties are similar, in some respects, to those of the ethnologist

who is sent on some museum expedition. The wealthy donor of the funds may wish to see a room filled with specimens on the return of the ethnologist, so that materials which have bulk and make a showing take precedence over detailed studies of the habits, traditions, languages, and descriptions of the people, because such studies require appreciation rather than inspection for evaluation. The zoölogical student may meet with just the same kind of difficulty. His institutional authorities often judge values by the cubic foot and pound, rather than by the quality of relations discovered. The student himself who has had an extensive collecting experience, in which quantity and variety have been the ideal, finds it difficult to return from a day's work with only a few pages of notes on the responses of the animals, and with perhaps only a few specimens.

With such an understanding of the general rules of the game we may turn to the application or art of ecology, to indicate its relation to general problems. With a grounding in the general principles of organic response to the total environment, one is able to see that the disturbances due to man are a problem in the adjustment of the highest type of animal, as a member of an animal association, to its complete environment. The "control of nature" for which men strive is the process of making the environments and associations *to order*. The disturbances in the natural order may be looked upon as so many huge experiments or trial activities in this process of adjustment.

If natural preserves are not made, how will the next generation be best grounded in the general principles of the science? Are these complex modified conditions the natural place to start the student, or should such problems be reserved for the maturely trained one? These disturbed fragmentary conditions may be likened to fragmentary fossils whose interpretation is attempted. A paleontologist whose only knowledge of animals was derived from such fragments, and who had never known a perfect living animal, would certainly be at a great disadvantage in such an investigation. The natural starting point therefore seems to be in as nearly natural normal environments and associations as is possible, and with such experience one is prepared for the more complex problems resulting from man's activity.

By way of conclusion, some of the main advantages of ecological surveys are:

1. The *record* of natural environments and their associations for future generations.

2. The study of natural biotic conditions giving a *perspective* not derived in any other way.

3. The clearer conception of the *dynamic relations* of the balance of nature, biotic base, and climax associations.

4. Emphasis of the *process and interpretative* phase of scientific investigation over that of purely descriptive study.

5. Facilitating the invention of multiple working hypotheses which bear upon animal responses in nature.

6. Furnishing important conceptions to the study of the *processes* of adaptation and the struggle for existence.

7. Furnishing important general principles of great value in applied ecology.

8. Furnishing one of the best methods of learning how to get acquainted with the *living aspect* of the animals of any region.

III. FIELD STUDY

"Is not the biological laboratory which leaves out the ocean and the mountains and meadows a monstrous absurdity? Was not the greatest scientific generalization of your times reached independently by two men who were eminent in their familiarity with living things in their homes?" — Brooks, 1899, p. 41.

In taking up field work, or any other kind of complex study, a definite working plan is of much value. For this reason this subject deserves more than a mere mention. Such a plan greatly aids in keeping in mind the general aim of the study, and particularly the lesser aims which develop with the analysis of the subject. It further aids in the proper orientation and subordination of allied subjects which crowd in from all directions.

For many students it is a good plan to make out a general outline of any proposed study as soon as possible after the work has been started. In the beginning it is difficult to realize the radiating relations of a subject, and the attempt at such plans aids in the perception of these relationships and becomes an important guide. Such an outline will need several revisions, but these changes will come with a broadening and deepening grasp of the subject. Perhaps the greatest value of such a plan is that it facilitates the conscious effort to seek a defi-

nite goal by maintaining a standard of measurement.

In addition to a comprehensive analytical plan others are useful. Particularly is this true when several lines of work are being done simultaneously or when the work must be interrupted frequently. Under such circumstances even a daily program may aid in utilizing many of the fragments of time which are so easily lost. In this way incomplete observations, verifications, and similar small items which are time-consuming may be made. These plans apply with particular force to field study when several lines of observation are being driven abreast. I have found it profitable to keep memoranda on note slips which will recall items needing further attention, at certain places in the field or on certain subjects. Thus, for example, if plans are suddenly changed and another locality is visited, the proper note slips indicating the points for special study at such a place are quickly secured, and one can hasten to the field prepared for the work of the day. Of course, similar plans are applicable to many kinds of work.

To learn how to study in the field, and not simply to collect, is one of the most important habits which a field naturalist and the ecologist has to acquire. This is one which he must, to a large degree, master alone, without the ready access to assistance, as is usually the case in the laboratory study. It is also a subject about which it is difficult to give useful suggestions, other than those of the most general nature.

Directions for collecting are, on the other hand, simpler and more accessible in the form of numerous manuals filled with practical suggestions.

Field study is not confined to observations alone, but to the securing of all kinds of evidence from the field which will aid in the interpretation of the field relations of animals. Thorough intimacy with the animals can only be acquired through repeated and prolonged excursions in the field. This may mean excursions at any hour of the day or night. Part of this familiarity is best acquired by an intensive study of some limited area or association, and by thus establishing a unit for comparison so that the differences in other places are more readily perceived and described.

Before selecting a limited area for study one should make a general examination of a much larger tract, so that one may be sure that the area selected is a fair sample and worthy of the special study. There are also many advantages in selecting areas little modified by man. Such modified areas may, to better advantage, be considered later; just as pathology should be studied after one is grounded in normal histology. Undoubtedly the normal, or its approximation, is the best foundation upon which to build, and here we have the educational argument for natural preserves for animals and their superiority over highly modified "parks" for the same purpose.

Having selected a locality, repeated and prolonged visits, careful observation, and description of the place and animals will enable one to acquire the de-

sired familiarity. For the study of the behavior of the animals concerned many observations can be made by remaining quiet, carefully concealed, and recording all observations. This method is particularly applicable to animals which live in exposed places, such as many insects, birds, and mammals. For other kinds, only indirect methods of observation are possible, or only when under controlled conditions. For the indirect methods of observation many forms of traps have been devised, traps not intended merely to receive the dead animal, but those also which will secure the animal and reveal something of its behavior. For the study of the habits and behavior of such animals as live in the soil or under bark, etc., both extensive collecting and examination of the animals in vivaria will also be necessary.

Fortunately for the student of mammals, birds, and fishes we have excellent guides for the technique of study and photographing of individual and associated kinds in the works of Kearton (1907), Chapman (1900), Herrick (1905), and Reighard (1908). It is very desirable that these methods be applied to the interrelations among the animals of an association. The student of behavior in nature has much to learn from many excellent studies of animal behavior which have been carried on in recent years by laboratory students. Fortunately the line between these two methods of study is breaking down to the mutual advantage of each. The border line between these two methods will give excellent re-

turns to any student well prepared in each line of work.

Another essential for good field work is a clear understanding of what ecological studies attempt to do. This implies some general conception of what is worth while ecologically; it assumes a point of view or other criterion which may be applied to test the trueness of one's aim. The ecologist will meet with much more than ecological facts, but it is to these that he should give primary attention. These accessory facts, no matter how interesting in themselves, should not divert him from the main course. The ecologist must select from this mass of experience those facts, inferences, and conclusions which help in the *interpretation* of the responses of animals to their complete environment. It is thus evident why the ecologist must have a clearly defined aim, with criteria for estimating values, or he will be at the risk of dissipating his energies. This phase of our problem as applied to the studies of a geologist, but applying with equal force to the ecologist, has been concisely expressed by Van Hise (1904, pp. 611–612) as follows: "I have heard a man say: 'I observe the facts as I find them, unprejudiced by any theory.' I regard this statement as not only condemning the work of the man, but the position is an impossible one. No man has ever stated more than a small part of the facts with reference to any area. The geologist must select the facts which he regards of sufficient note to record and describe. But such selection implies theories of

their importance and significance. In a given case the problem is therefore reduced to selecting the facts for record, with a broad and deep comprehension of the principles involved, a definite understanding of the rules of the game, an appreciation of what is probable and what is not probable; or else making mere random observations. All agree that the latter alternative is worse than useless, and therefore the only training which can make a geologist safe, even in his observations, is to equip him with such a knowledge of the principles concerned as will make his observations of value."

Early in field work one should learn that the collection of specimens is not the primary aim of excursions, that specimens are only *one* kind of facts, but that field study should be devoted to the accumulation of specimens, and to observations on the habits, activities, interrelations, and responses of animals, as well as to all facts, inferences, and suggestions which are likely to be of use in the interpretation of the problems studied.

We sometimes hear that reflections upon the work should be reserved for the return to the laboratory or study. This advice seems to be based upon the assumption that study in the field is not particularly stimulating and suggestive. On the other hand deliberating interpretatively in the midst of the problems under consideration is one of the most favorable conditions possible for the improvement of the quality and quantity of one's work. It should be recalled in this connection that Darwin and Wallace's evolu-

tionary theory did not *originate* in the laboratory, but while in the field in the midst of their studies, while working reflectively upon their observations and collections, as Brooks indicates in the quotation at the beginning of this chapter. The classic case of Bates discovering mimicry in his London study instead of in the forests of Brazil is to some minds not an argument for laboratory study, but one for field study. There are but few subjects which have suffered more from the preponderating influence of the laboratory.

To be sure, it may require more time to study in the field than if one collects specimens only, but it is economical in the long run. There are, of course, certain phases of more indirect observation which can be done best in the study or laboratory, but at present, field study, as contrasted with collecting, is a phase of effort urgently needing emphasis.

The processes of observation and field study and note taking are so intimately related that taking notes becomes one of the essential parts of careful observation. This is also one of the most difficult habits to acquire. The beginner is inclined to write them up, especially field notes, in the evening after his return from the field. Such notes are generally brief, lack details, and are usually of little value. Therefore the safest course to pursue is to describe fully whatever seems of value, then to go over these facts again and by further observations increase the number of items noted several times. These observations should be recorded *as soon as made*, for

generally the lack of notes means a lack of detailed observation. Some observations can be made only at long intervals, even of many years, others only with the return of another cycle of behavior, or of another season, and still others cannot be repeated. It is such considerations as these which emphasize the need of pursuing the safest course and recording *instantly* and fully all observations when made. An excess of notes is of very rare occurrence. In the effort to write carefully worded notes one has a very important check upon the tendency toward hasty observation, because such a description requires one to think over the observation before it can be expressed. This deliberation is thus made at the time when reobservation can be made to the best advantage, and calls attention to the weak points to which special consideration may perhaps be given a moment later, and thus affords a chance to complete the observation. Comstock (Insect Life, 1897, p. 323) has well summed up the taking of notes as follows: "Fill your notebook with descriptions, but digest them carefully, sifting out for publication only those that exhaustive study and repeated observation prove to be valuable. In making observations *be sure* you are right and then look again." And again as Van Hise (Science, N. S., Vol. XVI, p. 326) has said, "The difference between *bad* observation and *good* observation is that the former is *erroneous;* the latter is *incomplete.*"

Notes are generally taken in one of two forms, in a book or on loose slips of paper or cards (Hop-

kins, 1893; Sanderson, 1904). It seems to be very generally agreed that if a book is used it should be of small size, of about 4 x 6 inches, so that it may be conveniently carried in the pocket. For a permanent record such books are a great convenience when once indexed. But when using such notes, while preparing a report, they are not so convenient as the note slips, unless one limits such a report to the form of a narrative. About ten years ago the writer began using a form of notebook in which an aluminum cover held the loose note slips. Thus while in the field one has the advantage of a book with a firm writing surface, and also that of the loose-leaf plan. This form of cover is now used by a number of field naturalists. The disadvantage of the slips not being bound might be remedied in part by using some form of punched slips which are convenient for binding.

Each one must decide for himself which form of recording notes answers his needs most satisfactorily. There are advantages in uniformity, but with the variable nature of work, it is sometimes very convenient to use both methods of recording.

Some students have no method of recording their observations or reflections upon their lines of interest. This seems to be unwise and suggests a method of business without bookkeeping. The efficiency of some students is greater than that of others, not so much because they possess superior mental ability, but because they have superior methods of preserving whatever useful ideas occur to them, while the others,

from their lack of records, have no cumulative store upon which to draw. This is an important form of capital. Note keeping is readily seen to consist not only of observations, but also of suggestions, inferences, conclusions, and reflections of any kind which will facilitate methods of work and the interpretation of the facts.

In describing environments, it is desirable to use the same general method for different localities so that the descriptions may be comparable and show some degree of standardization. This method has been found very useful in taxonomic studies and has similar advantages here. A brief general statement of the most conspicuous features may precede, and be followed by detailed descriptions. The order may well vary with individual workers, but a uniform method is desirable throughout any single piece of work and has obvious advantages. Thus one practical plan applied to a forest habitat is, to describe the substratum, the soil, rock, etc., then the forest litter of organic débris, then the boles of the trees and the forest crown and its character, and finally the operation of those agencies which are causing changes in the forest and which will perpetuate or change it in the future. No practical forester would be content to shut his eyes to the future crop of wood, and in the study of animal habitats we must not be content to rest below such a commercial standard. To some this seems very theoretical, and yet a farmer who counts upon a crop in five months, or a forester, in fifty years, is not so branded, and

the ecologist need have no fear in using such practical methods. In other words, we should consider the future stages of the developing habitat and learn to perceive the evidences which show in which direction development or change is taking place; or to determine the "orderly sequence of external nature." Not only should the future be considered, but we should strive also to read the record backward and interpret the past in terms of processes now in operation. In this respect the point of view of the geologist who interprets the past in terms of present processes may well merit our attention. To understand our habitats they must be studied not only in their length and breadth, but also in depth — past and future — as they have all three dimensions.

The preceding remarks bear equally well upon observations of the activities of animals in nature, on account of the absence of controlled conditions, for these methods have almost as much significance as the study of the environments themselves; and equally careful observations and descriptions are essential, if the detailed processes of animal activities and their transformations are to be recorded.

An experienced naturalist finds that from year to year the amount of notes which he takes increases rapidly, and in a very direct ratio to the progress which he makes in his study. Good note taking is not a passive process, but one which calls for an alert mind. The prolonged interest which is necessary to secure detailed observations implies such a frame of mind.

Every one soon tires of any subject unless new features are constantly being discovered.

In the description of the associations in any given habitat, the problem is much simplified if one has a clear idea of dominance, knows how to recognize it, and understands some of its main implications. The dominant forms are the most common and powerful individuals in the association. They may or may not be the most conspicuous, from a superficial view. Conspicuousness may depend upon size, but dominance refers to large absolute numbers and to influence exerted. We may profitably compare an association of animals in a given habitat to a play upon the stage. The environment corresponds to the stage. The dominant members of the association correspond to the leading characters, the secondary species, always present, to the essential but subordinate characters. The individual animals adjust themselves to one another, especially to the dominant forms, and to the environment, as the personalities in the play adjust themselves to the dominant characters, to one another, and to the environment. In both groups some individuals are dominant, some used and useful, some are tolerated, others pick up the crumbs, still others are predatory or parasitic, and all must be mutually adjusted to one another and to the environment.

The number of dominant species within an association is relatively limited, a fact which holds for both plants and animals. A knowledge of perhaps 200 or 300 species of animals (and 150 plants)

will enable one to work advantageously in many localities (as in the state of Illinois). Of this number perhaps not more than about one half or one third can be considered dominant. Every one who has tried to make extensive local lists of species knows that it requires many years of collecting to secure a large number of species. These rare species are generally of quite minor importance ecologically. Considerations of this character should be encouraging to those who may be intimidated by the idea of large numbers of species. Then, of course, it should be remembered that there are many aspects of ecological work which do not meet with this variety of animals.

IV. THE COLLECTION, PRESERVATION AND DETERMINATION OF SPECIMENS

Ecological study does not end with collecting specimens, and it may not begin there. The importance of collecting and preserving specimens will vary with the phase of ecological study considered. In the field study of behavior of a single species there may be almost no collecting of animals but much collecting of notes; but if one is devoted primarily to the recognition and study of the composition of associations and their interrelations, much collecting will have to be done. Also, when studying the ecological relations of some taxonomic unit, as in aggregate ecology, the number of associates is so large that one must do rather extensive collecting. But even the exhaustive study of the behavior of any single species will necessitate considerable collecting. The necessity for this has been shown by Forbes (1880, The Food of Fishes, p. 20) as follows: "If one wishes to become acquainted with the black bass, for example, he will learn but little if he limits himself to that species. He must evidently study also the species upon which it depends for its existence, and the various conditions upon which *these* depend. He must likewise study the species with which it comes in competition, and the entire system

of conditions affecting their prosperity. Leaving out any of these, he is like one who undertakes to make out the construction of a watch, but overlooks one wheel; and by the time he has studied all these sufficiently, he will find that he has run through the whole complicated mechanism of the aquatic life of the locality, both animal and vegetable, of which his species forms but a single element."

Collecting is an important means of ecological study. This is particularly true in the early stages of such study, but as the student becomes familiar with species and comes to know many of them at sight, less collecting will be necessary, except in the case of very small species and in those studies which depend upon the total catch as a means of securing data, as, for example, the case of plankton organisms. On account of the large number of species, very few students will be able to determine them at sight, but this does not disqualify a student for beginning ecological study. The greatest aid in handling such a varied population is a numbering of the individuals, or lots of specimens, consecutively and recording the full data for them in the notebook. The question arises at once as to how many specimens are to be assigned to *one* number. No rigid rule can be followed, but in general it is safe to assign a single number to all specimens which agree in *all the fundamental data*, as date, place of capture, and exact habitat. And for my own part I number all individuals taken, upon which any special observations are made, as when a Phymatid is taken with a dy-

ing or dead honeybee, or a dragon fly is taken from the web of an *Argiope*. In this way the confusion which is particularly liable to creep into one's work, where he deals with a large number of species, and before familiarity with them is acquired, may be reduced to the minimum. For small animals I have found useful a very liberal use of vials, into which field numbers, corresponding to numbers in the field notes, are placed *immediately upon capture* of the specimens, and not minutes or hours later when the vials have become mixed, and recollection is less sharp. Specimens which have been thoroughly numbered may thus be sent to specialists for determination. This method uses up many numbers, but, fortunately, the supply is unlimited, and it gives greater precision to one's notes, and encourages detailed observations on individual animals.

In the eyes of many the determination of specimens is such a formidable task that they are at once repelled from any subject which involves numerous species. But as we have previously remarked, there are phases of ecological study which involve only a minimum amount of such work. On the other hand, one may readily have an undue fear of numerous species, but no one can doubt that the smaller number of species found upon mountains or in the far north gives to a beginner certain advantages for study. But if one's studies are confined to the more restricted habitats, the number of species involved is comparable to the more favored localities mentioned.

An accurately determined series of specimens, conveniently arranged, will be an important aid in one's studies. Two forms of arrangement of such determined series are very helpful; one being synoptic or systematically arranged, and the other ecologically, by associations or by a topical arrangement in harmony with the subjects being investigated. With the use of such series and proper caution, aided by the best keys in the literature, one may hope to make many of his own determinations and thus economize his time.

There are many ways to secure the initial series of determined specimens, and some of these are the following: Our governmental departments, both national and state, and many of our large museums, universities, and academies, have numerous experts who are quite willing and even eager to aid earnest students who wish to have specimens determined. Then, in addition, there are many expert amateurs who are equally liberal, so that when all the sources of aid are considered, the list becomes a surprisingly long one. This is the fact that should be called to mind when considering large numbers of species. A student therefore does not need to work alone, but may have the coöperation of a large number of able and willing collaborators. Naturally we turn for aid to our United States National Museum as one of the first sources of assistance, to the Smithsonian Institution, and to the various scientific departments of the U. S. Department of Agriculture, particularly to the Bureaus of Plant Industry,

Biological Survey, and Entomology. These sources alone are able to determine almost any reasonable series of specimens, particularly if they are well preserved. Arrangements for such determinations can probably be made by addressing the proper authorities.

The museums of our larger cities, as the American Museum of Natural History of New York, the Carnegie Museum at Pittsburgh, the Field Museum of Chicago, and many smaller state and local museums are able to give very efficient aid in this line. Other local institutions are the State Universities and Experiment Stations, and the local natural history surveys, which often exist under the guise of a geological or agricultural organization. Frequently they are qualified and willing to do this work.

In very difficult cases it may be necessary to have recourse to Cassell's Naturalist's Universal Directory (Boston, 1905), in order to find the address of some specialist in a foreign land, who can help, but generally Americans are the best informed upon their own fauna.

Supplementary to, and in some cases a necessary substitute for, a reference series of authentically determined specimens, is one which the student is able to name for himself, by the study of the literature. Without some special training this may become dangerous ground to tread upon, but every now and then some young student begins in this way and develops such care in determining his own collections, that the method cannot be wholly

condemned. Such work in itself has fascinations, and one may easily occupy all one's time with it. From the ecological standpoint to stop with determinations only would be like acquiring a certain vocabulary, and stopping before learning how to use the language. Ecological work aims to use the names of species as the most concise method of referring to kinds of animals whose interrelations are to be described and interpreted. Taxonomy is the tool.

V. REFERENCES TO SCIENTIFIC TECHNIQUE

1. The Scientific Method.
2. Directions for Collecting and Preserving Specimens, Photographing, Surveying, and Other Phases of Technique.
3. The Preparation of Papers for Publication and Proof Reading.

1. The Scientific Method

CHAMBERLIN, T. C.

1897. The Method of Multiple Working Hypotheses. Jour. Geol., Vol. V, pp. 837–848.

1906. The Method of the Earth Sciences. Pop. Sci. Mo., Vol. LXVI, pp. 66–75. Inter. Cong. of Arts and Sciences, St. Louis, Vol. IV, pp. 477–487.

Very important papers and worthy of careful study.

GILBERT, G. K.

1886. The Inculcation of Scientific Method by Example, with an Illustration drawn from the Quaternary Geology of Utah. Amer. Jour. Sci., (3), Vol. XXXI, pp. 284–299.

1887. Special Processes of Research. Amer. Jour. Sci., (3), Vol. XXXIII, pp. 452–473.

MELDOLA, R.

1895. The Speculative Method in Entomology. Trans. Ent. Soc., London, 1895, pp. XLVIII–LXXIII.

VAN HISE, C. R.

1902. The Training and Work of a Geologist. Science, N. S., Vol. XVI, pp. 321–334.

KEYES, C. R.
1898. The Genetic Classification of Geological Phenomena. Jour. Geol., Vol. VI, pp. 809–815.
Valuable for its discussion of the criteria used in genetic studies.

VAN HISE, C. R.
1904. The Problems of Geology. Jour. Geol., Vol. XII, pp. 589–616; Inter. Cong. Arts and Sciences, St. Louis, Vol. IV, pp. 525–548. 1906.
An excellent discussion of the energy, agent, and process method of investigation. I have seen no similar discussion applied to biological or zoölogical subjects.

BOAS, F.
1896. The Limitations of the Comparative Method of Anthropology. Science, N. S., Vol. IV, pp. 901–908.
A suggestive paper for the student of ecology who uses the comparative method in his own work.
1904. The History of Anthropology. Science, N. S., Vol. XX, pp. 513–524.
Application of the genetic and historical method to the study of man.

MILL, J. S.
1881. A System of Logic, Ratiocinative and Inductive: Being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation. Eighth Edition. pp. 659. New York.

PEARSON, K.
1900. The Grammar of Science. Second Edition. pp. 548. London.

JEVONS, S.
1879. Principles of Science. Third Edition. pp. 786. London.
Certain chapters are of special interest.

CRAMER, F.
1896. The Method of Darwin. A Study in Scientific Method. pp. 232. Chicago.

MacDougal, Robt.
1905. On the Discrimination of Critical and Creative Attitudes. Jour. Philos. Psy. and Sci. Methods, Vol. II, pp. 287–293.

LeBon, G.
1898. The Life History of Scientific Ideas. Pop. Sci. Mo., Vol. LII, pp. 251–254.

2. Directions for Collecting and Preserving Specimens, Photographing, Surveying, and Other Phases of Technique

There is such an abundance of literature on the technique of collecting and preserving specimens, and so much of it can easily be secured by any earnest student, that space will not be taken to discuss these subjects in detail. Reference will simply be made to the main convenient sources of information. It should perhaps be mentioned that very few of these papers have been especially prepared from the standpoint of the animal ecologist. The student must select and devise his methods from all available sources.

I have included in this list a few references on the subject of camping, photography, and the use of instruments needed in the determination of the physical features of the environment. A few miscellaneous papers which are suggestive on methods of technique are also added.

Many Authors.
1891–1899. Bulletin 39, U. S. National Museum. Parts *A* to *O*.
Contain directions for collecting and preserving a great variety of animals, including marine animals,

mollusks, insects, spiders, myriapods, reptiles, amphibians, birds, birds' eggs and nests, mammals, etc.

ANONYMOUS.

1896. Manual for Army Cooks. pp. 306. Washington.
The Manual used by the cooks in the U. S. Army. It includes chapters on camp cooking, a subject of much importance in certain ecological surveys.

1905. Terms used in Forestry and Logging. Bull. 61, Bureau of Forestry, U. S. Dept. Agr. pp. 53.
Useful in the descriptions of forest conditions.

1904. Instructions to Field Parties and Descriptions of Soil Types. Bureau of Soils, U. S. Dept. Agr. pp. 198.
Useful in the description of soils in the study of subterranean animals.

BANKS, N.

1907. A "Census of Four Square Feet." Science, N. S., Vol. XXVI, p. 637.
A criticism of McAtee (1907).

1909. Directions for Collecting and Preserving Insects. Bull. 67, U. S. Nat. Mus. pp. 135.
An excellent manual. Should be in the hands of every student of insects.

BRETSCHER, K.

1902. Beobachtung über die Oligochaeten der Schweiz, VI. Folge. Rev. Suisse de Zoöl., Ann. Soc. Zoöl. Suisse et du Mus. d'His. Nat. de Geneve, Tome 10, pp. (1–29).

1904. Die xerophilen Enchytraeiden der Schweiz. Biol, Centralbl., Bd. XXIV, pp. 501–513.
Quantitative studies of earthworms in the soil.

BRUNNER, J.

1912. Tracks and Tracking. pp. 219. New York. Outing Publishing Co.
An illustrated guide for the identification of mammal

and bird tracks or foot prints. Devoted mainly to game and fur-bearing animals. Very valuable to the student of live animals in nature. Many of our smaller species are worthy of similar treatment.

Burns, F. L.

1901. A Sectional Bird Census. Wilson Bulletin, N. S., Vol. VIII, pp. 84–103.

A quantitative study of the birds found breeding on an area of one square mile. Other similar studies should be made.

Chapman, F. M.

1900. Bird Studies with a Camera. With Introductory Chapters on the Outfit and Methods of the Bird Photographer. pp. 218. New York.

The title clearly indicates the character of this book.

Comstock, J. H.

1897. Insect Life. pp. 349. New York.

Directions for the study of insects.

Clements, F. E.

1905. Research Methods in Ecology. pp. 334. Lincoln, Nebraska.

Important for methods of study in plant ecology, partly also applicable to animals; photography, and instruments for the study of environments.

Dahl, F.

1901. Was ist ein Experiment, was Statistik in der Ethologie? Biol. Centralbl., Bd. XXI, pp. 675–681.

1903. Winke für ein wissenschaftlicher Sammeln von Thieren. Sitzungs-Ber. der Gesell. naturfor. Freunde zu Berlin. Jahrg. 1903, pp. 444–475.

This contains, in addition to its suggestions on collecting, an interesting outline or classification of animal habitats (Cf. also Enderlein, 1908, pp. 72–77). This is not a genetic classification. Dahl's list of habitats will prove very suggestive to the student

who wishes to develop the genetic system of classification. Ultimately we must, of course, develop the latter system.

1904. Kurze Anleitung zum wissenschaftlichen Sammeln und zum Conservieren von Thieren. pp. 59. Jena.
An enlarged edition of the preceding paper.

Davenport, C. B.
1904. Statistical Variation with Special Reference to Biological Variation. Second, Revised Edition. pp. 223. New York.

Forbes, S. A.
1907. An Ornithological Cross-Section of Illinois in Autumn. Bull. Ill. State Lab. Nat. His., Vol. VII, pp. 305–335.
1908. The Mid-Summer Bird Life of Illinois: A Statistical Study. Amer. Nat., Vol. XLII, pp. 505–519.

Gibson, W. H.
1905. Camp Life in the Woods and the Tricks of Trapping and Trap Making. pp. 300. New York.
A book for boys, but not without value to the older student of live animals.

Flahault, C., and Schröter, C.
1910. Phytogeographical Nomenclature. Reports and Propositions, III^e Cong. Inter. de Bot. 1910. Bruxelles. pp. 28. Zurich.
A very valuable discussion of ecological nomenclature for plants. Defines the use of such terms as biology, ecology, habitat, association, formation, etc. It is very desirable that the plant and animal ecologists coöperate as much as possible in this subject.

Hensen, V.
1887. Ueber die Bestimmung des Plankton's oder des in Meere treibenden Materials an Pflanzen und Thieren; nebst Anhang. Fünfter Ber. der Komm. zur wissensch. Untersuch. d. deutschen Meere in Kiel

für die Jahre 1882 bis 1886, pp. 1–107, III–XVIII, Berlin.

This appears to be the original account of quantitative studies as applied to plants and animals of an association. These methods have been extended to the sea bottom by Petersen, to fresh water by many students, to land animals mainly by Dahl, and in recent years to plants by Clements and others.

Herrick, C. L.

1905. Home Life of Wild Birds. Revised Edition. pp. 255. New York.

Very valuable for suggestions on the study of live birds and how to photograph them.

Hopkins, A. D.

1893. Note and Record Keeping for the Economic Entomologist. U. S. Dept. Agr., Div. Ent., Insect Life, Vol. VI, pp. 103–108.

Job, H. K.

1910. How to Study Birds. A Practical Guide for Amateur Bird-Lovers and Camera-Hunters. pp. 272. New York. Outing Publishing Co.

Intended primarily for beginners in bird study, but contains valuable practical advice on methods of studying and photographing live birds which will aid the ecologist. Consult also Kearton (1907), Chapman (1900), and Herrick (1905).

Kearton, R.

1907. Wild Life at Home: How to Study and Photograph It. New and Revised Edition. pp. 204. London.

Kephart, H.

1912. The Book of Camping and Woodcraft. pp. 331. Fifth Edition. Outing Publishing Co.

This is the best all-round book on the technique of camping and living in the wilderness which I have seen. It includes direction for selecting outfits,

making camps, cookery, pests in the woods, blazes and survey lines, rations, emergency foods, getting lost, accidents, etc.

KNAUTHE, K.

1907. Das Süsswasser, chemische, biologische, und bakteriologische Untersuchungsmethoden unter besonderer Berücksichtigung der Biologie und der fischereiwirtschaftlichen Praxis. pp. 663. Neudamm.

A very important work on the technique of fresh water biology.

LEE, A. B.

1900. The Microscopist's Vade Mecum. A Handbook on the Methods of Microscopic Anatomy. Fifth Edition. pp. 532. Phila.

Very useful for methods of preserving delicate animals, and those in which the detailed structure of the animal must be studied.

LIVINGSTON, B. E.

1906. The Relation of Desert Plants to Soil Moisture and to Evaporation. Carnegie Inst. Pub. No. 50. pp. 78.

Methods of determination of moisture content of the soil and the air.

MCATEE, W. L.

1907. Census of Four Square Feet. Science, N. S., Vol. XXVI, pp. 447–449.

A quantitative study of the species of invertebrates and seeds found on the forest floor and on a meadow.

1912. Methods of Estimating the Contents of Bird Stomachs. The Auk, Vol. XXIX, pp. 449–464.

1912. The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in Protecting Animals from their Enemies. Proc. Acad. Nat. Sci. Phila., 1912, pp. 281–364.

An important critical study of the value of feeding experiments, conducted in captivity, as a method of deter-

mining normal food habits. The method is strongly condemned. Valuable series of references.

NEUMAYER, G. VON.

1906. Anleitung zu Wissenschaftlichen Beobachtungen auf Reisen. Dritte Auflage, Bd. 1, pp. 842; Bd. 2, pp. 880. Hanover.

A very important work, particularly for the traveling naturalist. Chapters by specialists, valuable references on collecting natural history specimens, and other phases of scientific exploration.

PEARL, R.

1911. Biometric Ideas and Methods in Biology; their Significance and Limitations. Scientia, Vol. X, pp. 101–119.

PETERSEN, C. G. JOH., and JENSEN, P. B.

1911. Valuation of the Sea. 1. Animal Life of the Sea-Bottom, its Food and Quantity. Rep. of the Danish Biol. Sta. to the Board of Agriculture, Vol. XX. pp. 76. Translated from Fiskeri-Beretning for 1910. Copenhagen.

Methods and results of a quantitative study of animals on the sea-bottom. A very important paper. Descriptions and figures of the apparatus used.

REIGHARD, J.

1908. Methods of Studying the Habits of Fishes, with an Account of the Breeding Habits of the Horned Dace. U. S. Bur. of Fisheries Bull., Vol. XXVIII, pp. 1111–1136.

1908. The Photography of Aquatic Animals in their Natural Environment. Bull. U. S. Bur. of Fisheries, Vol. XXVIII, pp. 41–68.

These papers also contain references to others on the habits of fishes.

KING, L. A. L., and RUSSELL, E. S.

1909. A Method for the Study of the Animal Ecology of the

Shore. Proc. Roy. Phys. Soc. of Edinburgh, Vol. XVII, No. 6, pp. 225–253.

Sanderson, E. D.
1904. A Card-Index System for Entomological Records. U. S. Dept. Agr., Div. Ent., Bull. 46, pp. 26–34.
Contains references to other methods of recording notes.

Simpson, C. B.
1903. Photographing Nets of Hydropsyche. Proc. Ent. Soc. Wash., Vol. V, pp. 93–95.

Sumner, F. B.
1910. An Intensive Study of the Fauna and Flora of a Restricted Area of the Sea Bottom. Bull. U. S. Bur. of Fisheries, Vol. XXVIII, pp. 1225–1263.
A study on our coast along lines similar to those of C. G. J. Petersen's "Det Videnskabelige Udbytte af Kanonbaaden 'Hauchs' Togter I de Danske Have Indenfor Skagen I Aarene" 1883–1886. 1893. pp. 464. Atlas. Copenhagen.

Transeau, E. N.
1908. The Relation of Plant Societies to Evaporation. Bot. Gaz., Vol. XLV, pp. 217–231.
Methods of studying the relative humidity of the air in various plant associations, also applicable to certain studies of animals.

Wainwright, D. B.
1905. A Plane Table Manual. Department of Commerce and Labor, Report U. S. Coast and Geodetic Survey for 1905. Appendix No. 7, pp. 295–341.
In making local studies the plane table may be very helpful.

Wright, A. H.
1907. A Graphic Method of Correlating Fish Environment and Distribution. Amer. Nat., Vol. XLI, pp. 351–354.

Wilson, H. M.
1905. Topographical Surveying. Second Edition. New York.
Directions for camping, emergency surgery, photography, etc., pp. 811–884.

In concluding this list of references I would suggest to the student the desirability of securing the following catalogues or lists of publications. A glance at the lists in this volume will show that a surprisingly large number of the papers or works are governmental publications, many of which have long been out of print, but many may still be secured from the different departments or from the Superintendent of Documents at Washington, D.C.

1. U. S. Geological Survey. List of Publications, including maps. Washington, D.C.
2. Superintendent of Documents. Lists of publications of the U. S. Department of Agriculture. Washington, D.C.
3. Smithsonian Institution. List of publications. Washington, D.C.
4. U. S. National Museum. List of publications. Washington, D.C.
5. U. S. Bureau of Fisheries (formerly U. S. Fish Commission). List of publications. Washington, D.C.
6. For list of dealers in second-hand books see Banks' Bull. 81, U. S. National Museum, pp. 117–118. This is one of the best methods of securing many publications which are out of print.

3. *The Preparation of Papers for Publication and on Proof Reading*

The preparation of papers for publication is a practical phase of study and an art, or form of technique, about which the zoölogical student is liable to hear but little. There may be a great economy of effort, and much time saved, if early in

his work the student realizes the need of cultivating the *habit* of preparing all manuscripts in a form suitable for publication. While there is much variation in details, yet within certain limits there is a certain amount of standardization which should become *habitual.* Departures from such a standard necessitate much loss of time which must be devoted to revisions and corrections. One may work for years and fail to realize this fact, until he attempts to adjust his habits of writing to the requirements of the editors of scientific publications. The following references are intended to cover the main aspects of the preparation of manuscripts and the reading of proof.

Lewes, George Henry (Edited by F. N. Scott).

1891. The Principles of Success in Literature. pp. 163. Boston. Allyn and Bacon.

A very sane little book on writing, a subject on which it is difficult to receive and apply advice.

Wendell, B.

1899. English Composition. pp. 316. New York.

Fernald, J. C.

1896. English Synonyms and Antonyms with Notes on the Correct Use of Prepositions. Tenth Edition. pp. 564. New York.

1904. Connectives of English Speech. The Correct Usage of Prepositions, Conjunctions, Relative Pronouns and Adverbs Explained and Illustrated. pp. 324. New York.

Allbutt, T. C.

1905. Notes on the Composition of Scientific Papers. pp. 164. London. Macmillan Company.

This book is by an experienced medical editor and contains many practical suggestions.

RICKARD, T. A.

1910. A Guide to Technical Writing. Second Edition. pp. 172. San Francisco. Mining and Scientific Press.

Intended primarily for writers on mining, and yet it contains much that is useful and suggestive to zoologists particularly the chapters on the need of simplicity in the language of science, and on the value of standardization.

WARMAN, P. C.

1903. A Plea for Better English in Science. Science, N. S., Vol. XVIII, pp. 563–568. Reprinted with revision, 1910. Washington.

DAVIS, W. M.

1911. The Disciplinary Value of Geography. Pop. Sci. Mo., Vol. LXXVIII, pp. 105–119, 223–240.

An illuminating paper on the "art of presentation" of scientific results in oral and written form.

1909. The Systematic Description of Land Forms. Geogr. Jour., Vol. XXXIV, pp. 300–318.

1909. Glacial Erosion in North Wales. Quart. Jour. Geol. Soc., Vol. LXV, pp. 281–350.

1910. Experiments in Geographical Description. Bull. Amer. Geogr. Soc., Vol. XLII, pp. 401–435.

1911. The Colorado Front Range. A Study in Physiographic Presentation. Ann. Associa. Amer. Geogr., Vol. I, pp. 21–83.

The four preceding papers are in many respects models of presentation. They exemplify the process method applied to *regions*, a phase of much importance in certain ecologic studies, particularly ecological surveys. The last two papers are rather detailed applications of the same ideas. A very profitable study may be made of the method of presentation in these papers.

DeVinne, T. L.

1902. The Practice of Typography. Correct Composition. A Treatise on Spelling, Abbreviations, the Compounding and Division of Words, the Proper Use of Figures and Numerals, Italic and Capital Letters, Notes, etc., with Observations on Punctuation and Proof-reading. Second Edition. pp. 476. New York.

Perhaps the highest American authority on all the subjects discussed.

Wood, G. M.

1909. Suggestions to Authors of Papers Submitted for Publication by the United States Geological Survey with Directions to Typewriters. U. S. Geol. Survey. pp. 50. Washington.

Can be secured gratis from the Survey.

Anonymous.

1903. Government Printing Office Manual of Style for Use in Composition and Proof Reading. pp. 191. Washington, D.C.

Vaux, C. B.

1910. How to Prepare a Paper for Publication. Bull. No. 4. Wistar Inst. Anat. and Biology. pp. 20. Phila.

1910. Style Brief. A Guide for Authors in Preparing Copy and Correcting Proof of Professional Papers and for the Use of Editors and Printer, adopted as the Standard of the Journals Published by the Wistar Institute of Anatomy and Biology, Philadelphia. pp. 32. First Edition. Baltimore.

The Wistar Institute publishes the "Journal of Experimental Zoölogy," which is devoted to "original researches of an experimental or analytical nature" on many branches of zoölogy, including *ecology* and general physiology. The "Style Brief" can be secured from the Institute.

ORCUTT, W. D.
1912. The Writer's Desk Book. pp. 184. New York. F. A. Stokes Co.
A useful handbook on punctuation, capitalization, spelling, abbreviations, numerals, etc., and with an appendix on weights and measures.

WOOLLEY, E. C.
1907. Handbook of Composition. A Compendium of Rules Regarding Good English, Grammar, Sentence Structure, Paragraphing, Manuscript Arrangement, Punctuation, Spelling, Essay Writing and Letter Writing. pp. 239. Boston.

VI. IMPORTANT SOURCES OF INFORMATION ON THE LIFE HISTORIES OF INSECTS AND ALLIED INVERTEBRATES

Insects are to-day one of the dominant forms of life and are present in almost every large animal association or habitat. They therefore form an important element in a large number of ecological studies. And although facts of ecological significance have been accumulating for many years they are so widely scattered that to find them when needed is quite a serious problem. To aid in such a search the following references are given. It should be remembered that spiders, mites, and myriapods are commonly included in entomological literature and are therefore included in this list. The list is not intended as a substitute for the more elaborate sources such as the Zoölogical Record and similar standard works to be found in large libraries, but it includes publications that are more likely to be within the grasp of teachers and students not located at library centers. Many of these are public documents, and even if out of print, can easily be secured from second-hand dealers.

A student who has access to large libraries will find the following paper very valuable in suggestions as to the methods of finding the literature on many general zoölogical subjects.

MINOT, C. S.

1896. Bibliography. A Study of Resources, pp. 149–168. Biol. Lectures, Wood's Holl, 1895. Boston.

(Alphabetically arranged.)

ALDRICH, J. M.

1905. A Catalogue of North American Diptera. Smithsonian Misc. Coll., Vol. XLVI, No. 1444. pp. 680.

Contains an extensive bibliography on flies.

ANONYMOUS.

1906. Catalogue of Publications Relating to Entomology in the Library of the U. S. Department of Agriculture. Library Bulletin 55. pp. 562. Washington.

BANKS, N.

1892. A Synopsis, Catalogue, and Bibliography of the Neuropteroid Insects of Temperate North America. Trans. Amer. Ent. Soc., Vol. XIX, pp. 327–373.

1898–1905. Bibliography of the More Important Contributions to American Economic Entomology, Parts VI, VII, and VIII. U. S. Department of Agriculture, Bureau of Entomology.

A continuation of the work begun by Henshaw (1889–1896).

1900. A List of Works on North American Entomology. U. S. Dept. Agr., Div. Ent., Bull. No. 24 (N. S.). pp. 95.

1902. An Index to Bulletins Nos. 1–30 (N. S.), (1896–1901), of the Division of Ent. U. S. Dept. Agr., Div. Ent., Bull. No. 36 (N.S.). pp. 64.

1910. A List of Works on North American Entomology. U. S. Dept. Agr., Div. Ent., Bull. 81. pp. 120.

This and the preceding edition (1900) form a very useful index to the systematic literature of insects, spiders, myriapods, etc.

1910. Catalogue of the Nearctic Hemiptera-Heteroptera. Amer. Ent. Soc. pp. 103. Philadelphia.

1910. Catalogue of Nearctic Spiders. U. S. Nat. Mus., Bull. 72. pp. 80.
In the absence of special bibliographies these catalogues are the most convenient avenue to the literature.

Bethune, C. J. S.
1900. General Index to the Thirty Annual Reports of the Entomological Society of Ontario, 1870–1899. pp. 76. Ontario Dept. Agr.

Beutenmüller, W.
1891. Bibliographical Catalogue of the Described Transformations of North American Coleoptera. Jour. N. Y. Micros. Soc., Vol. VII, pp. 1–52.
1890. Preliminary Catalogue of the Described Transformations of the Odonata of the World, pp. 165–179. In Lamborn, R. H., Dragonflies *vs.* Mosquitoes. New York.
1893. On the Food Habits of the North American Rhynchophora. Jour. N. Y. Ent. Soc., Vol. I, pp. 36–43, 80–88.
1896. Food-Habits of North American Cerambycidæ. Jour. N. Y. Ent. Soc., Vol. IV, pp. 73–81.

Chittenden, F. H.
1893. Note on the Food Habits of Some Species of Chrysomelidæ. Proc. Ent. Soc. Wash., Vol. II, pp. 261–267.
1897. General Index to the Seven Volumes of Insect Life, 1888–1895. U. S. Dept. Agr., Div. Ent.

Commissioner of Agriculture.
1876. The General Index of the Agricultural Reports of the Patent Office for 1837–1861, and of the Department of Agriculture for 1862–1876. Washington.

Comstock, J. H.
1879. Report upon Cotton Insects. U.S. Dept. Agr. pp. 511.
This report, like those of the U. S. Entomological Com-

mission, gives very full accounts of the habits and life histories of certain species and gives particular attention to their predaceous and parasitic enemies. The predaceous insects are seldom given as detailed study as the vegetable-feeding kinds.

Coquillett, D. W.

1881. Larvæ of Lepidoptera. Tenth Ann. Rep. State Ent. Ill., pp. 145–186.

Descriptions, figures, and keys to many common larvæ.

Cresson, E. T.

1887. Synopsis of the Hymenoptera of America, North of Mexico. Trans. Amer. Ent. Soc., Supplem. Vol., 1887, Pt. 2. Catalogue of Species and Bibliography, pp. 155–350. Philadelphia.

Currie, R. P., and Caudell, A. N.

1911. An Index to Circulars 1 to 100 (Second Series) of the Bureau of Entomology. U. S. Dept. Agr., Bur. Ent., Circular No. 100. pp. 49.

The circulars contain a large amount of information on life histories of insects.

Dimmock, G., and Knab, F.

1904. Early Stages of Carabidæ. Bull. No. 1, Springfield Mus. Nat. Hist. pp. 55. Springfield, Mass.

Dodge, C. R.

1888. The Life and Entomological Work of the Late Townend Glover. U. S. Dept. Agric., Div. Ent., Bull. No. 18 (O. S.). pp. 68.

Dyar, H. G.

1894. A Classification of Lepidopterous Larvæ. Ann. N. Y. Acad. of Sci., Vol. VIII, pp. 194–232.

Edwards, H.

1889. Bibliographical Catalogue of the Described Transformations of North American Lepidoptera. U. S. Nat. Mus., Bull. 35. pp. 147.

Felt, E. P.
1905–06. Insects Affecting Park and Woodland Trees. Mem. 8, N. Y. State Mus., Vol. I, pp. 1–332, a435–a459, 1905; Vol. II, pp. 333–877, 1906.
Excellently illustrated, and with numerous references. This report and Packard's Forest Insects form an excellent guide to the life histories and literature of forest insects.
1899. Memorial of Life and Entomologic Work of Joseph Albert Lintner, Ph. D. N. Y. State Mus., Bull. 24, Vol. V, pp. 303–611.
Contains an index to Lintner's thirteen reports as State Entomologist of New York. These reports contain rather full references and good summaries of life histories.

Folsom, J. W.
1906. Entomology with Special Reference to its Biological and Economic Aspects. pp. 485. Philadelphia.
A very useful bibliography is given on pp. 409–466.

Forbes, S. A.
1885. General Indexes to the First Twelve Reports of the State Entomologists of Illinois. App. to Fourteenth Rep. State Ent. Ill. pp. 120. Springfield.
1909. Contents and Index of the Reports of the State Entomologist of Illinois, XIII–XXIV. 1884–1908. pp. 157. Office of State Entomologist.

Forbes, W. T. M.
1906. Field Tables of Lepidoptera. pp. 141. Worcester, Mass. Keys for the determination of larvæ.
1910. A Structural Study of Some Caterpillars. Ann. Ent. Soc. Amer., Vol. III, pp. 94–132.
Contains a very useful bibliography (pp. 125–127).

Forbush, E. H., and Fernald, C. H.
1896. The Gypsy Moth. Mass. Board Agr. pp. 495. Boston.

Also discusses predaceous and parasitic animals which prey upon the Gypsy Moth.

Hart, C. A.

1895. On the Entomology of the Illinois River and Adjacent Waters. Bull. Ill. State Lab. Nat. Hist., Vol. IV, pp. 149–284.

Keys to immature stages of aquatic insects and many biological observations.

Henshaw, S.

1887. The Entomological Writings of Dr. Alpheus Spring Packard. U. S. Dept. of Agr., Div. Ent., Bull. No. 16. pp. 49.

Biological observations.

1889–96. Bibliography of the More Important Contributions to American Economic Entomology, Parts I–V, and index. U. S. Dept. of Agr., Div. Ent.

Hubbard, H. G.

1885. Insects Affecting the Orange. U. S. Dept. Agr., Div. Ent. pp. 227.

Johannsen, O. A.

1903, 1905. Aquatic Nematocerous Diptera. N. Y. State Mus., Bull. No. 68, pp. 328–448; Bull. No. 86, pp. 76–327.

Immature stages of several families are rather fully treated and valuable references on life histories given.

MacGillivray, A. D.

1903. Aquatic Chrysomelidæ and a Table of the Families of Coleopterous Larvæ. Bull. No. 68, N. Y. State Mus., pp. 288–331.

Gives references to the most important papers on the immature stages of beetles.

Needham, J. G., and Betten, C.

1901. Aquatic Insects in the Adirondacks. Bull. No. 47, N. Y. State Mus., pp. 383–612.

Keys to orders to immature aquatic insects; keys to Mayfly and dragon-fly nymphs.

Needham, J. G.
1903. Life Histories of Odonata, Suborder Zygoptera. Bull. No. 68, N. Y. State Mus., pp. 218–276.
Keys to nymphs.
1905. Ephemeridæ. Bull. No. 86, N. Y. State Mus., pp. 17–59.
Keys to genera of adults and to nymphs.
1908. Report on the Entomologic Field Station Conducted at Old Forge, N. Y., in the Summer of 1905. Bull. No. 124, N. Y. State Mus., pp. 156–248.
Life histories of crane flies, Tipulidæ; table of larval habits, p. 239, and fish food.

Office of Experiment Stations, U. S. Dept. Agric.
1889. Experiment Station Record, Vol. I to date.
1903. General Index to Experiment Station Record, Vols. 1–12, 1889–1901, and to Exp. Sta. Bull. No. 2. pp. 671.
Useful for references to current literature on economic species, before they have appeared in the more slowly published bibliographies.

Packard, A. S.
1890. Forest Insects. U. S. Dept. Agr., Fifth Rep. U. S. Ent. Comm. pp. 957.
Almost an encyclopedia on forest insects, insects listed by food plants. Very useful.

Pierce, W. D.
1907. On the Biologies of the Rhynchophora of North America. Ann. Rep. Neb. St. Bd. Agr., 1906–07, pp. 247–319.
This is an annotated list of breeding and food habits of the snout and bark beetles. References to the literature, index of plants and beetles. Very useful.
1908. A List of Parasites Known to Attack American Rhynchophora. Jour. Econ. Ent., Vol. I, pp. 380–396.

Riley, C. V., Packard, A. S., and Thomas, C.
1878. First Annual Report of the U. S. Entomological Com-

mission for the Year 1877, Relating to the Rocky Mountain Locust, etc. U. S. Geol. Surv. (Hayden). pp. 477.

Discusses predaceous and parasitic animals which prey upon the locust.

1880. Second Report of the U. S. Entomological Commission for the Years 1878 and 1879, Relating to the Rocky Mountain Locust, and the Western Cricket, etc. U. S. Dept. Interior. pp. 322.

Discusses predaceous and parasitic animals which prey upon the locust.

Riley, C. V.

1880. Food Habits of the Longicorn Beetles or Wood Borers. Amer. Ent., Vol. III, pp. 237–239, 270–271.

1881. General Index and Supplement to the Nine Reports on the Insects of Missouri. U. S. Dept. of Interior. U. S. Ent. Comm., Bull. No. 6. pp. 178.

1885. Fourth Report of the U. S. Entomological Commission, etc. (On the Cotton and Boll Worm.) U. S. Dept. Agr. pp. 399.

Schwarz, E. A.

1890. Food-Plants and Food-Habits of Some North American Coleoptera. Proc. Ent. Soc. Wash. Vol. I, pp. 231–233.

Scudder, S. H.

1889. Classified List of Food Plants of American Butterflies, drawn from Scudder's Butterflies of the Eastern United States. Psyche, Vol. V, pp. 274–278.

1901. Index to North American Orthoptera. Occasional Papers of the Bost. Soc. Nat. Hist., VI. pp. 436.

This is a complete alphabetical index to the literature of the species of North American Orthoptera — a unique and very useful work.

Thomas, C., Middleton, N., and Martin, J.

1881. Descriptive Catalogue of Larvæ. Tenth Rep. State Ent. Ill., pp. 60–140.

Description and keys to saw-fly and Lepidopterous larvæ.

TOWNSEND, C. H. T.

1893. A General Summary of the Known Larval Food-habits of the Acalyptrate Muscidæ. Can. Ent., Vol. XXV, pp. 10–16.

WARD, H. B., WHIPPLE, G. C., and others.

Fresh Water Biology. (In press.) New York.

This work consists of chapters by numerous specialists on the various groups of fresh-water animals including insects, gives keys for the determination of specimens, short chapters on their general biological relations, and references to the literature.

VII. THE LAWS OF ENVIRONMENTAL CHANGE, OR THE "ORDERLY SEQUENCE OF EXTERNAL NATURE"

THE DYNAMIC AND PROCESS RELATIONS OF THE ENVIRONMENT

"Of all the truths relating to phenomena, the most valuable to us are those which relate to the order of succession. On a knowledge of these is founded every reasonable anticipation of future facts, and whatever power we possess of influencing those facts to our advantage." — JOHN STUART MILL.

"To study life we must consider three things: first, the orderly sequence of external nature; second, the living organism and the changes which take place in it; and, third, the continuous adjustment between the two sets of phenomena which constitutes life." — W. K. BROOKS.

"The truth, indeed, is, that in physical inquiries, the work of theory and observation must go hand in hand, and ought to be carried on at the same time, more especially if the matter is very complicated, for there the clue of theory is necessary to direct the observer. Though a man may begin to observe without any hypothesis, he cannot continue long without seeing some general conclusion arise; and to this nascent theory it is his business to attend, because, by seeking either to verify or to disprove it, he is led to new experiments, or new observations. He is led also to the very experiments and observations that are of the greatest importance, namely to those *instantiæ crucis*, which are the *criteria* that naturally present themselves for the trial of

every hypothesis. He is conducted to the places where the transitions of nature are most perceptible, and where the absence of former, or the presence of new circumstances, excludes the action of imaginary causes. By this correction of his first opinion, a new approximation is made to the truth; and by the repetition of the same process, certainty is finally obtained. Thus theory and observation mutually assist one another; and the spirit of system, against which there are so many and such just complaints, appears, nevertheless, as the animating principle of inductive investigation. The business of sound philosophy is not to extinguish this spirit, but to restrain and direct its efforts."

— J. PLAYFAIR, "Illustrations of the Huttonian Theory of the Earth," Edinburgh, 1802, pp. 524–525.

THE facts and ideas with which the animal ecologist needs to become acquainted are so widely scattered that a large amount of selective reading is necessary. The ecologist must read, select, and become an organizing center of things ecological. All of the facts and conceptions which he needs are not even confined to zoölogical or biological literature. In seeking an understanding of any problem, conventional groupings of the sciences and their arbitrary boundaries must not bar one from fertile fields. Many of the conceptions of the physical sciences, due to their more advanced stage of development, anticipate the future development of biology. This is particularly true of their dynamic conceptions. For this reason we should not hesitate to utilize and deliberately strive to secure development along similar lines in animal ecology. Elsewhere I have stated (An Ecological Survey in Northern Michigan, 1906, pp. 11, 12) that: "It is thus very apparent

that as soon as ecological phenomena are investigated dynamically and expressed in terms of processes, this science will of necessity become more closely correlated with those allied sciences which have already availed themselves of such methods. . . . It seems a very simple matter to give assent to the idea of the law of change, yet in its practical application this simplicity often vanishes at once when it is seen that it involves the relation of cause and effect. . . . As this method of thinking is not generally understood, it is occasionally applied in such a crude and general sense that its bearing cannot be grasped when applied to special or concrete problems. There can be no question as to the general validity of this method, but what is now needed is to know how these processes are combined and related to produce particular environmental conditions or situations. That these difficulties are not confined to the ecologist alone, but are obstacles which arise in any attempt at scientific interpretation, is worthy of special notice. We are thus able to see why certain naturalists, apparently not recognizing or understanding the developmental processes which scientific ideas undergo, nor being acquainted with the tendencies of interpretation, dynamically considered, now making such rapid headway in ecological botany, geography, physiography, geology, and psychology, are inclined to look upon such attempts in biology as merely a fad or personal peculiarity of the student, and not of any particular consequence. Such ideas confuse the incidental with the essential and suggest a com-

plete failure to grasp the situation or to realize the fundamental importance of stating explanations in terms of processes. Furthermore, in several of the allied sciences, the methods of dynamical interpretation have already made considerable advance. Here, then, is a resource, at present largely unworked by many biologists, where a wealth of ideas and explanations lies strewn over the surface and only need to be picked up in order to be utilized by those acquainted with this method of interpretation. . . . If the signs of the times are now read correctly, the most striking advance in scientific methods of thinking during the present century will be in the direction of interpretation from the standpoint of processes — dynamically."

For these reasons I have begun the list of literature with certain references which deal with the dynamic relations of the environment. These publications are particularly valuable not only for this method of treatment, but also for their content. These papers clearly emphasize the "orderly sequence of external nature," a conception which must be grasped much more than superficially, if one is to interpret the development or evolution of environments. Although this is an essential part of our problem, as has been so well expressed by Brooks, yet this phase is probably one of the least understood by zoölogists. And as long as zoölogical students lack the proper training this condition will continue. To neglect this aspect in the training of an ecologist is like neglect of chemical training in a physiologist

or of a physiological training in a psychologist. For one who is ignorant of the principles of "orderly sequence," or successions of changes occurring in the physical, vegetational, and animal environments, it is manifestly impossible to realize their development; and the application of such principles to the interpretation of practical problems is utterly beyond his grasp. We are thus able to see that although the phrase "orderly sequence of external nature" is fundamentally a simple conception, it is not grasped without effort, training, and careful investigation.

Obviously it is impossible to arrange the series of references with perfect satisfaction. The arrangement which will serve one purpose will not another, and for this reason it has been necessary to arrange the lists in more than one order. Certain general references, or some intended to facilitate the acquirement of the general *point of view*, are given first, and others are arranged alphabetically. For example, the papers listed on the processes of change in the physical and vegetational environment are approximately in an order in which they may profitably be studied to make the view as concrete as possible. It is primarily not the abstract idea of the principle of change, which is relatively easy to grasp, but to be able to apply it to any condition or location and to make it a guiding principle is very difficult. And judging from my own observation upon others and my own experience this method is very rarely mastered, if at all, unless it is actually worked out in

some concrete case, and later expanded to its logical consequences.

Only a few references are given on general physiology, metabolism, and allied subjects, but those given furnish a valuable index to further literature. Only the most arbitrary line can be drawn between papers dealing with habits, behavior, and individual ecology, and for this reason most of the references selected are arranged alphabetically.

Particular attention should be called to the fact that it is not to be assumed that the various authors strive to make the points to which attention is here called; they may or may not do so. My aim is to call attention to the *utility* of the publications from the *standpoint* advocated throughout the book.

From this point onward in this book the references form its main feature. For this reason it is important that one should not get an exaggerated idea of the value of the literature. It is perhaps true that a large part of the best ecological work has been done with little knowledge of other ecological writings. This was of course particularly true of the early workers, and the best work of to-day does not come from the largest library centers. A student looking over these lists, and finding that he has access to relatively few papers, may conclude that all effort is of no avail. The greatest need is not all or even a majority of the publications on the *general field*, but the relatively limited number which bear directly upon the problem at hand and enough of the general papers to aid him in a general orientation.

It may be of some comfort to the isolated student, with his small shelf of books, to realize that there are perhaps not a half-dozen libraries in America which contain *all* the references given in this book. The nearer one reaches the boundaries of our knowledge, the smaller the amount, and often the smaller the value of the literature, and the greater the value of a proper orientation, which comes only with a grasp of general principles.

(The laws of physical and vegetational changes and their influence upon animals. The dynamic or process relation of the environment.)

BANCROFT, W. D.

1911. A Universal Law. Science, N. S., Vol. XXX, pp. 159–179.

The law of adjustment or response to strain. A very important paper viewed from the dynamic and process standpoint.

HENDERSON, L. J.

1913. The Fitness of the Environment. An Enquiry into the Biological Significance of the Properties of Matter. pp. 317. New York. The Macmillan Company.

Valuable ecologically because of its exposition of the orderly sequence and *regulatory* character of physico-chemical and physiological processes, and the application of chemical equilibria and the Phase Rule to metabolic changes. He says, "Now there can be no doubt that, when feasible, the ideal method — from the physico-chemical point of view — to describe a material system is in terms of the phase rule." p. 260.

Chamberlin, T. C., and Salisbury, R. D.
1904. Geology. Geologic Processes and their Results, Vol. I. pp. 654. New York.
To be considered from the standpoint of the *agents* and *processes* which change animal habitats and result in their "orderly sequence."

Van Hise, C. R.
1904. A Treatise on Metamorphism. U. S. Geol. Survey, Monog., Vol. XLVII, pp. 1–1286.
A formidable-looking volume on account of its size, but one which will abundantly repay a careful study of its method, aside from the value of the content, for problems related to animals of the soils, etc. Particular attention should be given to the formulation of dynamic principles, and the application of the process method.

Davis, W. M.
1909. Geographical Essays. pp. 777. New York.
Essays on the orderly sequence of changing land forms, or to the ecologist, the development of inland habitats, in so far as they are dependent upon the physiographic conditions.

Woodworth, J. B.
1894. The Relation between Baseleveling and Organic Evolution. Amer. Geol., Vol. XIV, pp. 209–235.
The influence of baseleveling factors in the development of the gross environment and upon evolution.

Adams, Chas. C.
1901. Baseleveling and its Faunal Significance, with Illustrations from Southeastern United States. Amer. Nat., Vol. XXXV, pp. 839–852.
The influence of baseleveling upon the sequence of changes in fresh-water and land habitats. (See Figures 4 and 5.)

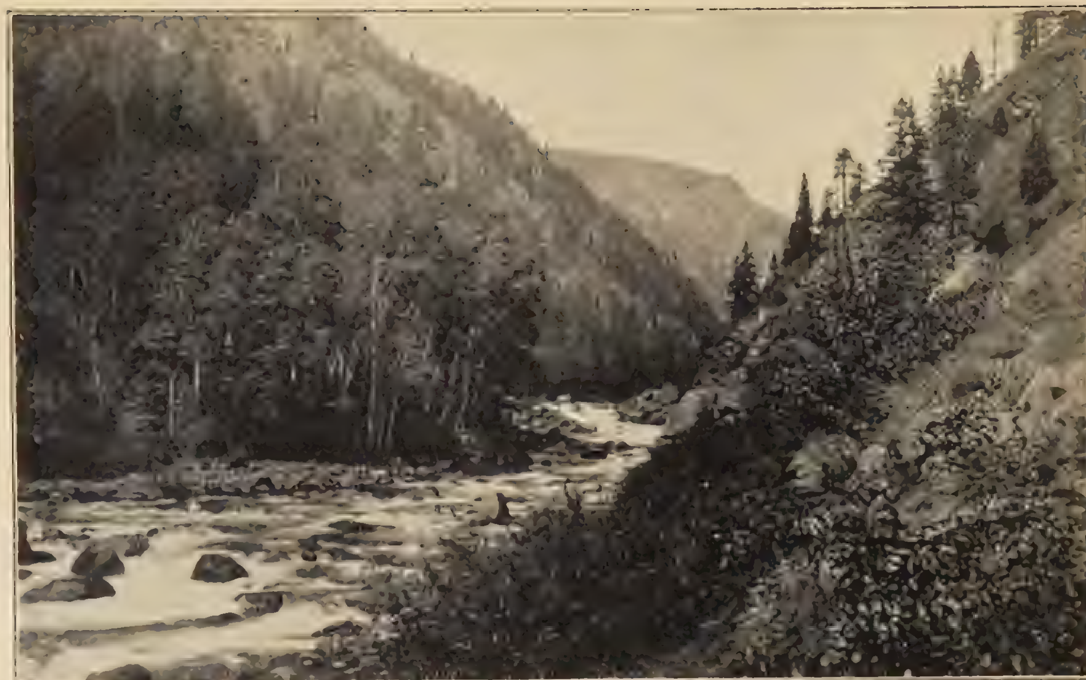

FIG. 4.—A small stream as an animal environment, with the preponderance of rapidly flowing water. Tumwater Cañon, near Wenatchee, Washington. Photo by W. B. McCallum.

FIG. 5. — A small river as an animal environment. The rapid water conditions of a stream in an early stage of topographic development, such as is shown in Fig. 4, is here replaced by long pools of relatively quietly flowing water, connected by narrow stretches of more rapidly flowing water. Wabash River, Bluffton, Indiana. Photo. by N. Miller and E. B. Williamson.

BRANDT, K.

1899. Ueber den Stoffwechsel im Meere. Wissen. Meeruntersuchungen, heraus. v. d. Komm. zur wissen. Unters. deutschen Meere in Kiel. N. F. Abth. Kiel, Bd. IV, pp. 213–230.

1901. Life in the Ocean. Smithsonian Report for 1900, pp. 493–506.

A translation of the preceding paper on the transformation of substance or "cycle of matter" in the sea. The extensive footnotes are omitted.

1902. Ueber den Stoffwechsel im Meere. 2 Abhand. Wiss. Meeresunt. heraus. v. d. Komm. zur wissen. Unters. deutschen Meere in Kiel, N. F. Bd. VI, Abth. Kiel, pp. 23–79.

1905. On the Production and Conditions of Production in the Sea. Rapports et Procés-Verbaux, Inter. Council for the Exploration of the Sea, Vol. III, Appendix D. Copenhagen.

Not seen by the writer. Johnstone states that it is a summary of the papers of 1899 and 1902.

JOHNSTONE, J.

1908. Metabolism in the Sea. pp. 206–298. In "Conditions of Life in the Sea." Cambridge, England.

BIRGE, E. A.

1907. The Respiration of an Inland Lake. Trans. Amer. Fisheries Soc., Vol. XXXVI, pp. 223–241.

1904. The Thermocline and its Biological Significance. Trans. Amer. Micros. Soc., Vol. XXV, pp. 5–33.

Two studies in the sequential changes in the lake habitat.

BIRGE, E. A., and JUDAY, C.

1911. The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and their Biological Significance. Wis. Geol. and Nat. Hist. Survey, Bull. No. 22. pp. 259.

Peters, A. W.
1907. Chemical Studies on the Cell and its Medium. Part II, Some Chemico-Biological Relations in Liquid Culture Media. Amer. Jour. Physiol., Vol. XVIII, pp. 321–346.
A study of changes in media and their biotic succession.

Cowles, H. C.
1911. The Causes of Vegetative Cycles. Bot. Gaz., Vol. LI, pp. 161–183. Also Ann. Associa. Amer. Geogr., Vol. I, pp. 1–20. 1912.
An important statement of the general principles and causes of vegetational changes. Includes a history of the subject.
1901. The Physiographic Ecology of Chicago and Vicinity; A Study of the Origin, Development, and Classification of Plant Societies. Bot. Gaz., Vol. XXXI, pp. 73–108, 145–182.
A study of changes in the vegetation from the process and genetic standpoint.

Clements, F. E.
1904. The Development and Structure of Vegetation. Bot. Surv. Nebraska, VII. pp. 175. Lincoln.
Deals with vegetative changes from the process standpoint.
1905. Research Methods in Ecology. pp. 334. Lincoln, Neb.

Crampton, C. B.
1911. The Vegetation of Caithness Considered in Relation to the Geology. pp. 132. Comm. for the Survey and Study of British Vegetation.
1912. The Geological Relations of Stable and Migratory Plant Formations. Scottish Bot. Rev., Vol. I, pp. 1–61.
Good examples of the process standpoint as applied to the vegetation.

WARMING, E. (Trans. by P. GROOM and I. B. BALFOUR.)
1909. Œcology of Plants. pp. 422. Oxford.
A treatise on the general principles of plant ecology, and an index to the literature.

ZON, RAPHAEL.
1906. Principles Involved in Determining Forest Types. Proc. Soc. Amer. Foresters, Vol. I, pp. 179–189.
Discusses the sequence of change in the forest.

OSTENFELD, C. H.
1908. On the Ecology and Distribution of the Grass-Wrack (*Zostera marina*) in Danish Waters. Rep. Danish Biol. Sta. to Board of Agriculture, Vol. XVI, 1908. Trans. from the Fiskeri-Beretning for 1907, pp. 1–62.
An important paper showing the controlling relation of marine vegetation upon animal associations and particularly the fish of the coast. References to related zoölogical papers.

MOORE, J. E. S.
1903. The Tanganyika Problem. pp. 371. London.
On pp. 107–119 Moore describes the invasion and succession of vegetation upon alluvial flats, recently drained. A graphic account of forest invasion. Apparently a little known study.

ERNST, A. (Trans. by A. C. SEWARD.)
1908. The New Flora of the Volcanic Island of Krakatau. pp. 74. Cambridge.
A study of the invasion of vegetation upon a new land surface formed by volcanic activity. Such studies as this aid one in breaking away from the older static view of vegetation and in seeing its more vital aspect.

VAUGHAN, T. W.
1911. The Geological Work of Mangroves in Southern Florida. Smithsonian Miscell. Coll. (Quart. Issue), Vol. LII, pp. 461–464.
Plants as agents in the formation of animal habitats.

WEISS, F. E.
1909. A Preliminary Account of the Submerged Vegetation of Lake Windermere as Affecting the Feeding Ground of Fish. Mem. and Pro. Manchester Lit. and Phil. Soc., Manchester Memoirs, 1908–1909, Vol. LIII, Mem. 11, pp. 1–9.

TRANSEAU, E. N.
1908. The Relation of Plant Societies to Evaporation. Bot. Gaz., Vol. XLV, pp. 217–231.
Shows vegetational control upon the relative humidity of the air.

FULLER, G. D.
1911. Evaporation and Plant Succession. Bot. Gaz., Vol. LII, pp. 193–208.
Further studies of the vegetational control of the relative evaporating power of the air.

SHELFORD, V. E.
1907. Preliminary Note on the Distribution of the Tiger Beetles (Cicindela) and its Relation to Plant Succession. Biol. Bull., Vol. XIV, pp. 9–14.
The sequence of vegetational changes which determine the habitats of a predaceous insect.
1912. Ecological Succession. IV. Vegetation and the Control of Land Animal Communities. Biol. Bull., Vol. XXIII, pp. 59–99.
An important paper correlating the development of the vegetation and the changing animal associations.

COOK, O. F.
1909. Vegetation Affected by Agriculture in Central America. U. S. Dept. Agr., Bur. Plant Industry, Bull. No. 145. pp. 30.
Vegetational change in the tropics as affected by man and its relation to plant succession.

FERNOW, B. E., and HARRINGTON, M. W., and others.
1893. Forest Influences. U. S. Dept. Agr., Forestry Div., Bull. No. 7. pp. 197.

Very valuable discussion of the atmospheric conditions in and about woodlands; temperature, evaporation, etc., in open and wooded areas. Not written from the process standpoint, but capable of such an interpretation. (See Figures 6 and 7.)

ADAMS, CHAS. C.

1905. The Postglacial Dispersal of the North American Biota. Biol. Bull., Vol. IX, pp. 53–71.

Climatic sequences applied to inland habitats and the succession of their associations.

1909. Isle Royale as a Biotic Environment. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 1–56.

An attempt is made to treat the environment and biota from both the dynamic or process standpoint — so far as the present processes are concerned — and genetically with regard to the development of the present conditions.

RUTHVEN, A. G.

1906. An Ecological Survey in the Porcupine Mountains and Isle Royale, Michigan. Ann. Rep. Mich. Geol. Surv. for 1905, pp. 17–55.

The environment and biotic associations are treated from the dynamic and genetic standpoint.

VIII. THE LAWS OF ORDERLY SEQUENCE OF METABOLISM, GROWTH, DEVELOPMENT, PHYSIOLOGICAL CONDITIONS, AND BEHAVIOR, OR "THE LIVING ORGANISM AND THE CHANGES WHICH TAKE PLACE IN IT"

THE DYNAMIC OR PROCESS RELATIONS OF THE ANIMAL

1. General Physiology and Development.
2. A Selection of Physiological and Ecological Papers.
3. Animal Behavior as a Process.
4. A List of Selected Reviews and Bibliographies.
5. A Selection of References on Life Histories and Behavior.

"Seeing, then, that in all cases we may consider the external phenomena as simply in relation, and the internal phenomena also as simply in relation; the broadest and most complete definition of Life will be — The continuous adjustment of internal relations to external relations." — HERBERT SPENCER.

"It is of the utmost importance, if we are to understand the behavior of organisms, that we think of them as dynamic — as processes, rather than as structures. The animal is something happening." — H. S. JENNINGS (1907).

NOT only is the environment subject to an orderly sequence of changes, but this same law applies with equal thoroughness to the living animal itself. The animal is an agent which transforms, in "an

orderly sequence," by its processes of metabolism, both energy and substance, resulting in growth, differentiation, multiplication, and behavior. These activities take place in an orderly manner and are dependent upon both energy and substance derived from the environment. For these reasons the processes or changes in metabolism, growth, development, and behavior, *in so far as they are responses to the orderly sequence of environmental changes, are ecological problems.* The changes in behavior during the life of the animal or the development of its behavior give one of the main clues to the physiological conditions which determine some of the most characteristic forms of responses, and finally as a result of all these activities and processes of adjustment to the conditions of life, a relatively mature and adjusted condition of the struggle for existence in animals and associations may be reached, the culmination of animal harmonies. For this reason studies in modifications of behavior are of fundamental ecological importance, because they consider behavior not only as ready-made, but also in the process of making. Such considerations as these make it desirable to include some of the most valuable and suggestive books and papers which deal with those general physiological processes influencing growth, development, multiplication, and behavior, and *particularly those which aid one in realizing their order or successive changes, or "orderly sequence."*

In studying the activities of the individual animal, the normal environment to which it is *attuned*

forms the natural unit or basis for study. All processes which modify or change such an optimum will stimulate the animal, cause responses and adjustments. There are many degrees or stages in the development of these optima which change with the functional rhythms and with the development of the animal. There are those conditions which influence the activity of certain functions or organs; those which influence the general vital processes in general, the vital optimum; those which appear to condition the best development of certain families, genera, etc.; and finally those of animal associations. Of course these grade imperceptibly into one another, and a single animal may in its development, traverse all of these stages in the development of its associational optimum. Optima thus have histories, and their development and laws of transformation are of the most fundamental ecological importance (Adams, 1904, 1909; Blackman, 1905, 1906; Shelford, 1911, 1912).

In the selection of these papers I have been guided by several considerations. Studies of common animals are given preference, also those papers which by their method of treatment and point of view are especially suggestive and may act as models for further study, and particularly those papers which treat of the activities from the standpoint of their changes, cycles, modifiability, and development. It is to such papers that we must look for suggestions regarding the methods or processes of adjustment between the animal and the environ-

ment. All of these papers are not equally ecological, but all will be of much utility in ecological work.

(General works are listed first, followed by special papers arranged alphabetically.)

1. General Physiology and Development

VERWORN, M.
1899. General Physiology. pp. 615. New York.
A very good general summary, but somewhat out of date. There is a German edition of 1909 (fifth).

ROSENTHAL, J.
1901. Lehrbuch der Allgemeinen Physiologie. pp. 616. Leipzig.

FÜRTH, O. VON.
1903. Vergleichende chemische Physiologie der niederen Tiere. pp. 670. Jena.
An excellent general work. Indispensable. Full references.

PÜTTER, A.
1911. Vergleichende Physiologie. pp. 721. Jena.

WINTERSTEIN, H. (Editor).
1910. Handbuch der vergleichenden Physiologie. (To be completed in four volumes.) Jena.

HAMMARSTEN, O. (Trans. by J. A. MANDEL.)
1911. A Text-Book of Physiological Chemistry. Sixth Edition. pp. 964. New York.

DAVENPORT, C. B.
1908. Experimental Morphology. pp. 509. New York.
Excellent summaries and full references to the influence of various stimuli upon growth and upon protoplasm.

Loeb, J.
1906. The Dynamics of Living Matter. pp. 233. New York.

Przibram, H.
1910. Experimental-Zoologie. 3. Phylogenese. pp. 315. Leipzig and Vienna.

Jennings, H. S.
1906. Behavior of the Lower Organisms. pp. 366. New York.
The general chapters are particularly helpful.

Morgan, T. H.
1907. Experimental Zoölogy. pp. 454. New York.
Summaries of a variety of experimental studies.

Semper, K.
1881. Animal Life as Affected by the Natural Conditions of Existence. pp. 472. New York.
"'The Physiology of *Organisms*,' in contradistinction to the Physiology of *Organs*, . . . [is] that branch of animal biology which regards the species of animals as actualities and investigates the reciprocal relations which adjust the balance between the existence of any species and the natural, external conditions of its existence, in the widest sense of the term." p. 33.

Jensen, P.
1907. Organische Zweckmässigkeit, Entwicklung und Vererbung vom Standpunkt der Physiologie. Jena. pp. 251.

Vernon, H. M.
1903. Variation in Animals and Plants. pp. 415. London.

Varigny, H. de.
1892. Experimental Evolution. pp. 271. New York.

Bachmetjew, P.
1901–1907. Experimentelle entomologische Studien vom physikalisch-chemischen Standpunkt aus. Bd. I. Temperaturverhältnisse bei Insekten. pp. 160.

Leipzig. 1901. Bd. II. Einfluss der Ausseren Faktoren auf Insekten. pp. 944. Sophia. 1907.
An extremely valuable index to environmental influences upon insects. Numerous summaries.

Herrick, C. L.
1906. Applications of Dynamic Theory to Physiological Problems. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 362–375.

Richards, H. M.
1910. On the Nature of Response to Chemical Stimulation. Science, N. S., Vol. XXXI, pp. 52–62.

Schäfer, E. A.
1912. The Nature, Origin and Maintenance of Life. Science, N. S., Vol. XXXVI, pp. 289–312.

Baskerville, C.
1905. Life and Chemistry. Science, N. S., Vol. XXI, pp. 641–648.

Morgan, T. H.
1910. Chance or Purpose in the Origin and Evolution of Adaptation. Science, N. S., Vol. XXXI, pp. 201–210.

Mathews, A. P.
1905. A Theory of the Nature of Protoplasmic Respiration and Growth. Biol. Bull., Vol. VIII, pp. 331–346.

Jennings, H. S.
1912. Age, Death and Conjugation in the Light of Work on Lower Organisms. Pop. Sci. Mo., Vol. LXXX, pp. 563–577.
Death is due to differentiation and not to a "running down" of the organism.

Lillie, F. R.
1909. The Theory of Individual Development. Pop. Sci. Mo., Vol. LXXV, pp. 239–252.

Holmes, S. J.
1904. The Problem of Form Regulation. Archiv für Ent-

wickelungsmechanik der Organismen (Roux), Bd. XVII, pp. 265–305.

1907. Regeneration as Functional Adjustment. Jour. Exp. Zoöl., Vol. IV, pp. 419–430.

Wilson, E. B.

1905. The Problem of Development. Science, N. S., Vol. XXI, pp. 281–294.

Sherrington, C. S.

1906. The Integrative Action of the Nervous System. pp. 411. New York.

The activity of the nervous system is viewed as a *regulatory* process.

The similar responses to diverse stimuli or the similar results produced by diverse causes are the conditions which make an analysis and the isolation of causes necessary. With departures from the normal and optimum into zones of stimulation and of unfavorable conditions many similar effects or results are produced. The similar results of extremes of high and low temperature as shown in Fischer's experiments on Lepidoptera, and the effects of high temperatures, aridity, and the lack of oxygen may be cited as examples. Such effects have an important bearing upon the subject of physical and chemical *limiting factors* which influence individuals, aggregations, and associations.

Blackman, F. F.

1905. Optima and Limiting Factors. Ann. of Bot., Vol. XIX, pp. 281–295.

"When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the 'slowest' factor." p. 289.

1908. The Manifestations of the Principles of Chemical Mechanics in the Living Plant. British Assoc. Adv. Sci., 1908, pp. 1–18.

Adams, Chas. C.

1904. On the Analogy Between the Departure from Optimum Vital Conditions and Departure from Geographic Life Centers. Science, N. S., Vol. XIX, pp. 210–211.

Greeley, A. W.

1901. On the Analogy Between the Effects of Loss of Water and Lowering of Temperature. Amer. Jour. Physiol., Vol. VI, pp. 122–128.

Zoethout, W. D.

1899. On Some Analogies Between the Physiological Effects of High Temperature, Lack of Oxygen, and Certain Poisons. Amer. Jour. Physiol., Vol. II, pp. 220–242.

Lyon, E. P.

1902. Effects of Potassium Cyanide and of Lack of Oxygen upon the Fertilized Eggs and the Embryos of the Sea-Urchin (*Arbacia punctulata*). Amer. Jour. Physiol., Vol. VII, pp. 56–75.

Packard, W. H.

1905. On Resistance to Lack of Oxygen and on a Method of Increasing this Resistance. Amer. Jour. Physiol., Vol. XV, pp. 30–41.

1907. The Effect of Carbohydrates on Resistance to Lack of Oxygen. Amer. Jour. Physiol., Vol. XVIII, pp. 164–180.

Fischer, E.

1903. Lepidopterologische Experimental-Forschungen. III. Allgem. Zeit. für Entomologie, Bd. VIII, pp. 221–228.

These experiments illustrate in a very striking manner how abnormally high and low temperatures produce the same kind of effect or response.

2. A Selection of Physiological and Ecological Papers
(Alphabetically arranged)

Clessin, S.
1897. Über den Einfluss der Umgebung auf die Gehäuse der Schnecken. Württemberg naturw. Jahreshefte 53, pp. 68–86.

Colton, H. S.
1908. Some Effects of Environment on the Growth of Lymnaea columella Say. Proc. Acad. Nat. Sci. Phila., 1908, pp. 410–448.

Keller, C.
1887. Humusbildung und Bodenkultur unter dem Einfluss tierischer Thätigkeit.
Not seen.

Knauthe, K.
1898. Zur Kenntnis des Stoffwechsels der Fische. Archiv f. d. gesammte Physiol. (Pflüger), Bd. LXXIII, pp. 490–500.

Lang, A.
1888. Über den Einfluss der festsitzenden Lebensweise auf die Thiere und über den Ursprung der ungeschlichtlichen Fortpflanzung durch Theilung und Knospung. pp. 166. Jena.

Locard, A.
1892. L'Influence des Milieux sur le Développement des Mollusques. pp. 140. Lyon.

Marshall, F. H.
1910. The Physiology of Reproduction. pp. 706. London.

Miller, N.
1909. The American Toad (Bufo lentiginosus americanus Le Conte). Amer. Nat., Vol. XLIII, pp. 641–668, 730–745.
A study of the natural history of a single species.

Riddle, O.
1909. The Rate of Digestion in Cold-Blooded Vertebrates,

— The Influence of Season and Temperature. Amer. Jour. Physiol., Vol. XXIV, pp. 447–458.

RUSSELL, E. S.

1908. Environmental Studies on the Limpet. Proc. Zoöl. Soc., London, 1907, pp. 856–870.

SCHIEMENZ, P.

1911. Vergleichung der Fruchtbarkeit von Seen und Flussen. Aus deutscher Fischerei. pp. 75–82. Neudamm.

A comparison of the relative productivity of fish in standing and running water environments.

SHELFORD, V. E.

1911. Physiological Animal Geography. Jour. Morph., Vol XXII, pp. 551–618.

An important paper. Explains the habitats and distribution of animals as due to physiological responses and characters. The dynamic and genetic standpoint of the present writer (p. 555) is erroneously *contrasted* with a physiological process. The dynamic includes all processes, the physiologic process is a species of this genus. The genetic is the application of processes to explain origins. The responsive and functional processes are dynamic in character.

1912. Ecological Succession. V. Aspects of Physiological Classification. Biol. Bull., Vol. XXIII, pp. 331–370.

Further studies along the lines of the preceding paper.

VIRE, A.

1896. Modifications Produced in the Organs of Sense and of Nutrition in Certain Arthropods by Confinement in Caves. Ann. Mag. Nat. Hist. (6), Vol. XVII, pp. 407–408.

VOSSELER, J.

1902. Über Anpassung und chemische Vertheidigungs mittel bei nordafrikanischen Orthopteren. Verh. Deutsch. Zool. Gesell. 1902, pp. 108–120.

1902–1903. Beiträge zur Faunistik und Biologie der Orthopteren Algeriens und Tunesiens. Zool. Jahrb. Abteilung f. Syst. Geog. u. Biol. der Tiere, Bd. XVI, pp. 337–404; Bd. XVII, pp. 1–98.

3. Animal Behavior as a Process

"The actual method of work is to first watch the organism under its natural environment, until one finds out all things it does. Then the environment is changed a little, to see what difference this makes in the behavior. We thus try all sorts of different ways of getting the animal to change its behavior, — including the application of definite chemical and physical reagents of most varied character. . . . We thus try to find the organism's system of behavior and the things that influence it, — becoming acquainted with the creature as we might get acquainted with a person with whom we are thrown much in contact."

— H. S. Jennings (1910).

"My object being the study of the correlative instincts of the young and adult in relation to all that could be learned about them in a natural environment, I have followed my usual custom of going out to the birds, instead of taking them into the laboratory. The facts which the laboratory can be made to yield are invaluable, but they belong to a different class from those for which we are now mainly in search, behavior under the usual or normal conditions." — F. H. Herrick (1910).

"As will be seen, these studies include both field and laboratory work, especially of the American species, and I have made the field work emphatic wherever at all practicable. I have elsewhere (1909, p. 157) [Jour. Exp. Zoöl., Vol. VII] emphasized the crying need for larger attention to this phase of experimental work, believing that in many cases it is all but impossible to secure trustworthy results as to behavior of animals where the work has been done under such unusual, unnatural and artificial conditions as most laboratory provisions afford. What right

has one to assume that the actions of an animal taken rudely from its natural habitat and as rudely imprisoned in some improvised cage are in any scientific sense an expression of its normal behavior, either physical or psychical? Is it within the range of the calculus of probability that conclusions drawn from observations made upon an animal in the shallow confines of a finger-bowl, but whose habitat has been the open sea, are wholly trustworthy? It is no part of my purpose to discredit the laboratory or laboratory appliances as related to such investigations. They are indispensable. But at the same time let it be recognized that they are at best but artificial makeshifts whose values, unless checked up by constant appeal to nature, must be taken at something of discount. . . . It seems to the writer that until one has been able to place his specimens under conditions approximating the natural, or has at least brought them to a state of semi-domestication, where in food-taking, evidence of health, etc., they are at ease, he has small right to dogmatize as to conclusions, or presume to make such conclusions the basis of so-called *laws of behavior*. Not a little of recent investigation along the lines of behavior has been vitiated at just this point, and must be repeated to be made trustworthy. The amazing mass of contradictory results which has loaded the literature of recent years is attributable to some extent to this misfortune." — C. W. Hargitt (1912).

"We are apt to contrast the extremes of instinct and intelligence, to emphasize the blindness and inflexibility of the one and the consciousness and freedom of the other. It is like contrasting the extremes of light and dark and forgetting all the transitional degrees of twilight. . . . Instinct is blind; so is the highest human wisdom blind. The distinction is one of degree. There is no absolute blindness on the one side, and no absolute wisdom on the other." — C. O. Whitman (1899).

The precedence here given to *changes in behavior* is in harmony with the emphasis which is put upon

processes and genetic phases or sequences throughout this book. As Holmes (1905, p. 108) has well pointed out, behavior consists of relatively fixed and relatively changeable responses, with intergradations. There are thus two avenues of approach which he sums up as follows (p. 112): "In the trial and error method the random character of the movement impresses us most; in the tropisms, the element of direct determination by the environment. Both of these factors run through the behavior of all animals, but they are mingled in various proportions in different forms. In the lives of most, if not all animals both are essential elements in the adjustment of the organism to its conditions of existence." And in regard to those responses which do not change in form with experience, he says (p. 106): "The element of spontaneous undirected activity is one of vast if not essential importance in the life of nearly all animals. The simpler animals profit by their varied experience, although they may not learn, and thus secure some of the advantages which it is generally considered the special function of intelligence to confer." Thus to the ecologist studying the sequences of changes in the environment, and changes in the organism, it is but natural and consistent for him to apply the same methods to behavior, in order to facilitate their mutual relations and aid in their interpretation. In a study of the environment we also have the relatively stable elements and the relatively rapidly changing ones, and any adequate understanding of animals must correlate these four variables: two relatively

changing, one in the organism and one in the environment; and two others relatively stable, one in the organism and the other in the environment.

JENNINGS, H. S.

1905. The Method of Regulation in Behavior and in Other Fields. Jour. Exp. Zoöl., Vol. II, pp. 473–494.

HOLMES, S. J.

1905. The Selection of Random Movements as a Factor in Phototaxis. Jour. Comp. Neurol. and Psychol., Vol. XV, pp. 98–112.

JENNINGS, H. S.

1905. Modifiability in Behavior. I. Behavior of Sea Anemones. Jour. Exp. Zoöl., Vol. II, pp. 447–472.

1906. Modifiability in Behavior, II. Factors Determining Direction and Character of Movement in the Earthworm. Jour. Exp. Zoöl., Vol. III, pp. 435–455.

1906. Behavior of the Lower Organisms. pp. 366. New York.

1907. Behavior of the Starfish (*Asterias Forreri* De Loriol). Univ. Calif. Pub. Zoöl., Vol. IV, pp. 53–185.

WALTER, H. E.

1907. The Reactions of Planarians to Light. Jour. Exp. Zoöl., Vol. V, pp. 35–162.

YERKES, R. M.

1901. The Formation of Habits in the Turtle. Pop. Sci. Mo., Vol. LVIII, pp. 519–525.

PEARL, R.

1904. On the Behavior and Reactions of Limulus in Early Stages of its Development. Jour. Comp. Neurol. and Psychol., Vol. XIV, pp. 138–164.

HADLEY, P. B.

1908. The Behavior of the Larval and Adolescent Stages of the American Lobster (Homarus Americanus). Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 199–301.

Mayer, A. G., and Soule, C. G.
1906. Some Reactions of Caterpillars and Moths. Jour. Exp. Zoöl., Vol. III, pp. 415–433.

Craig, W.
1908. The Voices of Pigeons Regarded as a Means of Social Control. Amer. Jour. Sociol., Vol. XIV, pp. 86–100.

Herrick, F. H.
1912. Organization of the Gull Community. Proc. Seventh Inter. Zoöl. Cong., Boston, 1907, pp. 156–158.

Yerkes, A. W.
1906. Modifiability of Behavior in Hydroides Dianthus V. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 441–449.

Yerkes, R. M., and Huggins, G. E.
1903. Habit Formation in the Crawfish, Cambarus affinis. Psychol. Rev.; Series of Monog. Suppl., Vol. IV, No. I; Harvard Psychol. Studies, Vol. I, pp. 565–577.

Yerkes, R. M.
1905. Animal Psychology and the Criteria of the Psychic. Jour. Phil., Psychol., and Sci. Methods, Vol. II, pp. 141–149.
1905. Concerning the Genetic Relations of Types of Action. Jour. Comp. Neurol. and Psychol., Vol. XV, pp. 132–137.

Allee, W. C.
1912. An Experimental Analysis of the Relation between Physiological States and Rheotaxis in Isopoda. Jour. Exp. Zoöl., Vol. XIII, pp. 269–344.
A study of the responses of pond and stream Isopods to natural and experimental conditions.

Washburn, M. F.
1908. The Animal Mind. pp. 333. New York.
For modifications of behavior by experience see pp. 205–269. Also many references on behavior.

4. A List of Selected Reviews and Bibliographies

1911. [Reviews of papers on animal behavior for 1910.] Jour. Animal Behavior, Vol. I, pp. 393–455, 465–470.
Reviews by Holmes, Turner, Wheeler, Watson, and Bohn.

JENNINGS, H. S.
1909. The Work of J. von Uexkuell on the Physiology of Movements and Behavior. Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 313–336.

CONGDON, E. D.
1908. Recent Studies upon the Locomotor Responses of Animals to White Light. Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 309–328.

MAST, S. O.
1910. Literature of the Past Year on the Behavior of Lower Organisms. Psychol. Bull., Vol. VII, pp. 267–280.
1911. Recent Literature on the Behavior of the Lower Invertebrates. Psychol. Bull., Vol. VIII, pp. 263–277.

YERKES, R. M.
1906. George Bohn's Studies in Animal Behavior. Jour. Comp. Neurol. and Psychol., Vol. XVI, pp. 231–238.

WASHBURN, M. F.
1908. French Work in Comparative Psychology for the Past Two Years. Jour. Comp. Neurol. and Psychol., Vol. XVIII, pp. 511–520.

WASHBURN, M. F. (Editor).
1912. Comparative Psychology Number. Psychol. Bull., Vol. IX, No. 8, pp. 281–313.
Reviews by Pearse, Turner, and Washburn.

COUES, E.
1877. Monograph of North American Rodentia. Rep. U. S. Geol. Surv. Terr. (Hayden), Vol. XI.
Contains on pp. 255–264 and 951–1081 an extensive bibliography of North American mammals, and includes much on their habits.

5. *A Selection of References on Life Histories and Behavior*

(Alphabetically arranged)

ANDREWS, E. A.

1906. Egg-laying of Crayfish. Amer. Nat., Vol. XL, pp. 343–356.

1904. Breeding Habits of Crayfish. Amer. Nat., Vol. XXXVIII, pp. 165–206.

BAKER, F. C.

1911. Ecology of Lymnæas. pp. 19–51. Lymnæidæ of North and Middle America Recent and Fossil. Special Pub. No. 3, Chicago Acad. Sciences.

BANTA, A. M.

1910. A Comparison of the Reactions of a Species of Surface Isopod with those of a Subterranean Species. Jour. Exp. Zoöl., Vol. VIII, Part I, Experiments with Light, pp. 243–310; Part II, pp. 439–488.

BELDING, D. L., and LANE, F. C.

1909. The Shellfisheries of Massachusetts: their Present Condition and Extent. Report upon the Mollusk Fisheries of Massachusetts, pp. 16–233. Boston.
Contains some excellent photographs of the habitat.

1910. A Report upon the Scallop Fishery of Massachusetts, including the Habits, Life History of *Pecten irradians*, its Rate of Growth, and Other Facts of Economic Value. pp. 150. Boston.

1911. The Life History and Growth of the Quahaug (*Venus mercenaria*). Rep. Mass. Comm. Fisheries and Game for 1910, pp. 18–128. Boston.
These papers are examples of applied ecology, and contain much on the life histories and habits of these mollusks.

BENDIRE, C.

1892. Life Histories of North American Birds with Special Reference to their Breeding Habits and Eggs, with

Twelve Lithographic Plates. Smithsonian Inst., Special Bull. No. 1. pp. 414.

1895. Life Histories of North American Birds, from the Parrots to the Grackles, with Special Reference to their Breeding Habits and Eggs. Smithsonian Inst., Special Bull. pp. 508.

Blackwall, J.

1873. Researches in Zoölogy. London.
Not seen by writer.

Böving, A. G.

1910. Natural History of the Larvæ of Donaciinæ. Inter. Revue der gesamten Hydrobiol. u. Hydrog., Bd. III, Biol. Suppl., Heft I, pp. 1–108.

Buttel-Reepen, H. von. (Trans. by M. H. Geisler.)

1907. Are Bees Reflex Machines? Experimental Contribution to the Natural History of the Honey-bee. pp. 48. Medina, Ohio.

Calkins, M. W.

1905. The Limits of Genetic and of Comparative Psychology. Jour. of Psychol., Vol. I, pp. 261–285 ; Inter. Cong. of Arts and Sciences, St. Louis, Vol. V, pp. 712–734.

Carpenter, F. W.

1908. Some Reactions of Drosophila, with Special Reference to Convulsive Reflexes. Jour. Comp. Neurol. and Psych., Vol. XVIII, pp. 483–491.

1910. Feeding Reactions of the Rose Coral (Isophyllia). Proc. Amer. Acad. Arts and Sciences, Vol. XLVI, pp. 149–162.

Casteel, D. B.

1911. The Discriminative Ability of the Painted Turtle. Jour. Animal Behavior, Vol. I, pp. 1–28.

Clarke, W. E.

1912. Studies in Bird Migration. Vol. I, pp. 323; Vol. II, pp. 346. London.
Bird migration may be studied as a response of the

animals to the conditions of their life, and the above work is a good example of the best kind of work being done along this line.

Cole, L. J.

1907. An Experimental Study of the Image-Forming Powers of Various Types of Eyes. Proc. Amer. Acad. Arts and Sci., Vol XLII, pp. 335–417.

A study of worms, insects, sow bug, snail, slug, and frogs.

1913. Direction of Locomotion of the Starfish (Asterias Forbesi). Jour. Exp. Zoöl., Vol. XIV, pp. 1–32.

Cole, L. W.

1907. Concerning the Intelligence of Raccoons. Jour. Comp. Neurol. and Psychol., Vol. XVII, pp. 211–261.

1912. Observations on the Senses and Instincts of the Raccoon. Jour. Animal Behavior, Vol. II, pp. 299–309.

Cole, L. W., and Long, F. M.

1909. Visual Discrimination in Raccoons. Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 657–683.

Colton, H. S.

1908. How Fulgur and Sycotypus Eat Oysters, Mussels and Clams. Proc. Acad. Nat. Sci. Phila., 1908, pp. 3–10.

Coker, R. E.

1906. The Natural History and Cultivation of the Diamond-Back Terrapin with Notes on other Forms of Turtles. Bull. No. 14, N. Carolina Geol. Survey, pp. 1–67.

Craig, W.

1909. The Expressions of Emotion in the Pigeons. I. The Blond Ring-Dove (*Turtor risorius*). Jour. Comp. Neurol. and Psychol., Vol. XIX, pp. 30–80.

Dawson, J.

1911. The Biology of Physa. Behavior Monographs, Vol. I, No. 4, pp. 1–120.

Behavior is related to the natural environment.

Davis, H. B.
1907. The Raccoon: A Study in Animal Intelligence. Amer. Jour. Psychol., Vol. XVIII, pp. 447–489.

Dean, B.
1892. The Physical and Biological Characteristics of the Natural Oyster Grounds of South Carolina. Bull. U. S. Fish Comm. for 1890, Vol. X, pp. 335–361.
Contains good illustrations of the oyster habitat.

Dimon, A. C.
1905. The Mud Snail: Nassa obsoleta. Cold Spring Harbor, Monogr. V. pp. 48.
A behavior study of a marine snail.

Embody, G. C.
1912. A Preliminary Study of the Distribution, Food, and Reproductive Capacity of Some Fresh-water Amphipods. Inter. Revue. der gesamten Hydrobiol. u. Hydrog., Biol. Suppl. III. Serie, Heft 2, pp. 1–33.

Enteman, M. M.
1902. Some Observations on the Behavior of Social Wasps. Pop. Sci. Mo., Vol. XLI, pp. 339–351.

Fabre, J. H. (Translated.)
1901. Insect Life. Souvenirs of a Naturalist. pp. 320. London.

Fabre, J. H. (Trans. by Miall, B.)
1912. Social Life in the Insect World. pp. 327. London.

Florentin, R.
1899. Études sur la Faune des Mares Salées de Lorraine. Ann. des Sci. Nat. Zoöl. (8^{e} S.), Tome X, pp. 209–350.

Forel, A. (Trans. by Wheeler, W. M.)
1904. Ants and Some Other Insects. Religion of Sci. Library No. 56. pp. 49. Chicago.

Forel, A. (Trans. by Yearsley, M.)
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IX. THE CONTINUOUS PROCESS OF ADJUSTMENT BETWEEN THE ENVIRONMENT AND THE ANIMAL, WITH SPECIAL REFERENCE TO OTHER ORGANISMS

The Dynamic or Process Relation of Animal Associations and Aggregations

1. The Struggle for Existence.
2. The Dynamic Relations of Aggregations and Associations, with Special Reference to Animal Associations.
   a. The Relation of Animals to Pollination and to Plant Galls.
   b. Subterranean and Cave Associations.
   c. Selected References on Aggregations and Associations.

"Nothing is easier than to admit in words the truth of the universal struggle for life, or more difficult — at least I have found it so — than constantly to bear this conclusion in mind. Yet unless it be thoroughly engrained in the mind, the whole economy of nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood." — Darwin.

"Every reflective biologist must know that no living being is self-sufficient, or would be what it is, or be at all, if it were not part of the natural world, although no truth is easier to lose sight of. Living things are real things, . . . but their reality is in their interrelations with the rest of nature, and not in themselves." — W. K. Brooks. (1906.)

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1903. Birds in their Relations to Man. pp. 380. Phila. Extensive bibliography on the food of birds.

WHEELER, W. M.
1911. Insect Parasitism and its Peculiarities. Pop. Sci. Mo., Vol. LXXIX, pp. 431–449.
1910. The Effects of Parasitic and Other Kinds of Castration in Insects. Jour. Exp. Zoöl., Vol. VIII, pp. 377–438.

ZACHARIAS, O., and others.
1891. Die Tier- und Pflanzenwelt des Süsswassers. Bd. I, pp. 380; Bd. II, pp. 369. Leipzig.
Contains several valuable and suggestive papers on the general biological relations of fresh-water plants and animals.

2. The Dynamic Relations of Aggregations and Associations, with Special Reference to Animal Associations

"A group or association of animals or plants is like a single organism in the fact that it brings to bear upon the outer world only the surplus of forces remaining after all conflicts interior to itself have been adjusted. Whatever expenditure of energy is necessary to maintain the existing internal balance amounts

to so much power locked up, and rendered unavailable for external use. In many groups this latent energy is so considerable and is liable to such fluctuations, that a knowledge of its amounts and kinds, and of the laws governing its distribution, is extremely important to one interested in measuring or foreseeing the sum and character of the outward-tending activities of the class."

—S. A. Forbes (1883).

Möbius, K.

1883. The Oyster and Oyster-Culture. U. S. Comm. of Fish and Fisheries, Report of Comm. for 1880, Part VIII, pp. 683–751.

On pp. 721–729 the oyster is discussed as a member of a social community or "biocönosis." He describes the succession of animals due to the overfishing of the oyster beds and the invasion of cockles and edible mussels which close up the available space and prevent the return of the oyster. One of the earliest papers to recognize clearly a social community in animals. A very important paper, which also shows the method of applying the science of ecology.

Forbes, S. A.

1887. The Lake as a Microcosm. Reprint from Bull. Sci. Associa. of Peoria, Illinois, 1887, pp. 1–15.

Perhaps the first paper by an American naturalist recognizing the interrelations of the social community.

Wheeler, W. M.

1911. The Ant-Colony as an Organism. Jour. Morphology, Vol. XXII, pp. 307–325.

The ant colony is considered as a unit. This paper furnishes an excellent example showing how "individual ecology" may become transformed into an "associational" unit.

Möbius, K.

1893. Ueber die Thiere der Schleswig-Holsteinischen Aus-

terbänke, ihre physikalischen und biologischen Lebensvershältnisse. Sitzungsber. d. Kgl. preuss. Akad. d. Wiss. zu Berlin, Jhrg. 1893, I, pp. 67–92.

The physical and biological relations of the Schleswig-Holstein oyster bank as a social community are carefully described. The animals associated are listed (in all about 100 kinds, p. 80) and their relation to the oyster is shown.

FORBES, S. A.

1909. The General Entomological Ecology of the Indian Corn Plant. Amer. Nat., Vol. XLIII, pp. 286–301.

ESPINAS, ALFRED.

1878. Des Sociétés Animales. Second Edition. pp. 588. Paris.

Discusses associations of different species — parasites, commensals, mutuals, domestic animals; associations of the same species and related through nutrition — the colonial forms, as corals; associations based upon reproduction — the family; and associations based upon relation — as in a horde. Contains an extensive historical introduction. Valuable, although somewhat old.

PETRUCCI, R.

1906. Origine Polyphylétique, Homotypie, et Non Comparabilité directe des Sociétés Animales. L'Inst. de Sociologie (Solvay). Notes et Mémoires, Fascicule 7. pp. 126. Bruxelles.

The multiple or independent origin of "social" life in diverse lines of descent is emphasized and viewed from the comparative and phylogenetic standpoint.

WAXWEILER, E.

1906. Esquisse d'une Sociologie. L'Inst. de Sociologie (Solvay). Notes et Mémoires, Fascicule 2. pp. 306. Bruxelles.

A very important survey of sociology as a branch of

ethology or ecology. The history of ecology, and animal societies are parts which deserve special mention. A diagram, on p. 63, gives the subdivisions of ethology.

KROPOTKIN, P.
1903. Mutual Aid a Factor of Evolution. pp. 348. New York.

PARMELEE, M.
1913. The Science of Human Behavior. Biological and Psychological Foundations. pp. 443. New York. The Macmillan Company.
An important discussion of certain phases of animal and human responses. Communities are considered mainly from the standpoint of "aggregate ecology" and phylogeny. Little recognition is made of the "ecological association" as a fundamental unit in the study of human relations.

ADAMS, CHAS. C.
1909. The Ecological Succession of Birds. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 121–154.
A study of changes in bird associations.

SHELFORD, V. E.
1911. Ecological Succession.
I. Stream Fishes and the Method of Physiographic Analysis. Biol. Bull., Vol. XXI, pp. 9–34
1911*a*. II. Pond Fishes. Biol. Bull., Vol. XXI, pp. 127–151.
1911*b*. III. A Reconnaissance of its Causes in Ponds with Particular Reference to Fish. Biol. Bull., Vol. XXII, pp. 1–38.
1912. IV. Vegetation and the Control of Land Animal Communities. Biol. Bull., Vol. XXIII, pp. 59–99.
1912*a*. V. Aspects of Physiological Classification. Biol. Bull., Vol. XXIII, pp. 331–370.
A series of detailed studies on successions in standing

and running water, and upon land. Intimately related to the following.

1913. Animal Communities in Temperate America as Illustrated in the Chicago Region; A Study in Animal Ecology. Bull. Geogr. Soc. of Chicago, No. 5. pp. (In press.)

This is the most comprehensive and detailed *local study* of animal ecology thus far published from a distinctly modern standpoint.

Craig, W.

1908. The Voices of Pigeons Regarded as a Means of Social Control. Amer. Jour. Sociol., Vol. XIV, pp. 86–100.

Herrick, C. L.

1904. The Beginnings of Social Reaction in Man and Lower Animals. Jour. Comp. Neurol. and Psychol., Vol. XIV, pp. 118–123.

Herrick, F. H.

1912. Organization of the Gull Community. Proc. Seventh Inter. Zoöl. Cong., Boston, 1907, pp. 156–158.

Wesenberg-Lund, C.

1908. Die littoralen Tiergesellschaften unserer grosseren Seen. *a.* Die Tiergesellschaften des Brandungsufers. Inter. Revue der gesamten Hydrobiol. u. Hydrog., Bd. I, pp. 574–609.

Animal associations of a lake shore.

Jäger, G.

1874. Deutschlands Thierwelt nach ihren Standorten eingetheilt. Bd. I, pp. 400; Bd. II, pp. 367 + XXIV. Stuttgart.

A popular account of the fauna of Germany arranged according to habitat. A suggestive book to the student of local associations. Worthy of imitation.

Melander, A. L., and Brues, C. T.

1903. Guests and Parasites of the Burrowing Bee Halictus. Biol. Bull., Vol. V, pp. 1–27.

Gives a diagram of the Halictus biocönose on p. 27.

HUBBARD, H. G.
1894. The Insect Guests of the Florida Land Tortoise. U. S. Dept. Agr., Div. Ent., Insect Life, Vol. VI, pp. 302–315.

HUBBARD, H. G. (Appendix by SCHWARZ, E. A.)
1899. Insect Fauna of the Giant Cactus of Arizona: Letters from the Southwest. Psyche, Vol. VIII, Suppl., pp. 1–8, Appendix, pp. 8–14.

HUNTER, W. D., PRATT, F. C., and MITCHELL, J. D.
1912. The Principal Cactus Insects of the United States. U. S. Dept. Agr., Bur. Ent., Bull. No. 113. pp. 71.
In addition to the insects feeding upon cacti, their enemies or parasites are listed and also the scavengers, flower visitors, and incidentally associated species. This is a social community composed of 324 species of insects, and it forms an excellent foundation for a study of their interrelations. This is more ecological than is usually the case in economic reports.

MÖLLER, L.
1867. Die Abhängigkeit der Insecten von ihrer Umgebung. pp. 107. Leipzig. W. Englemann.
A very interesting and suggestive work. An excellent local habitat study from the standpoint of insects. Apparently not known to Dahl ('98, '03) in his brief outline of the history of ecology. Möller discusses the influence of climate, soil, plants, animal substances and man upon insects, and the influence of insects in the economy of nature.

LORENZ, J. R.
1863. Physicalische Verhältnisse und Vertheilung der Organismen im Quarnerischen Golfe. pp. 379. Wien.
An early and important study of the habitat and the plants and animals associated in the marine habitats. Apparently but little known. Also not mentioned by Dahl ('98, '03).

VERRILL, A. E.
1873. Report upon the Invertebrate Animals of Vineyard Sound and the Adjacent Waters, with an Account of the Physical Characters of the Region. U. S. Comm. Fish and Fisheries. Rep. on the Condition of the Sea Fisheries of the South Coast of New England in 1871 and 1872. Part I. Senate Misc. Doc. No. 61, 42d Cong., 2d Sess., pp. 295–778.
An early descriptive associational and habitat study of the marine animals of our coast. A kind of work, in its standpoint, far in advance of the times. It is remarkable that this well-known work has not been a model for other similar studies on our coast.

DAVENPORT, C. B.
1903. The Collembola of Cold Spring Beach, with Special Reference to the Movements of the Poduridae. Cold Spring Harbor Monogr. II. pp. 32.
An excellent study of a single group in a habitat, and its relation to behavior.
1903*a*. The Animal Ecology of the Cold Spring Sand Spit, with Remarks on the Theory of Adaptation. Decennial Pub. Univ. Chicago, Vol. X, pp. 157–176.
An associational study of a sea beach.

PETERSEN, C. G. JOH., and JENSEN, P. B.
1911. Valuation of the Sea. I. Animal Life of the Sea-Bottom, its Food and Quantity. Rep. of Danish Biol. Sta. to Board of Agriculture, Vol. XX, pp. 1–76. Transl. from Fiskeri-Beretning for 1910. Copenhagen.
The sea-bottom animals are studied as a community. The most important study of the kind known to the writer. Similar work should be done in American waters.

WARMING, E., WESENBERG-LUND, C., and others.
1904. Sur les 'vads' et les sables maritimes de la mer du nord.

Kon. Danske Vid. Selsk. Skrift., Bd. VII, R. II, pp. 48–56.

The sandy flats of the sea coast of Jutland and Holland are treated as a biotic association, and from a modern ecological standpoint.

Baker, F. C.

1910. The Ecology of the Skokie Marsh Area, with Special Reference to the Mollusca. Bull. Ill. State Lab. Nat. Hist., Vol. VIII, pp. 441–499.

A descriptive account of local molluscan associations near Chicago.

1911. The Molluscan Fauna of Tomahawk Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts and Letters, Vol. XVII, pp. 200–246.

An associational study of molluscan succession. One of the very few of its kind.

Hancock, J. L.

1911. Nature Sketches in Temperate America. pp. 451. Chicago.

A discussion of the habitats of Orthoptera is given on pp. 317–418, and a classification of them on pp. 419–433, based upon the egg-laying sites.

Dahl, F.

1899. Das Leben der Vögel auf den Bismarckinseln nach eigenen Beobachtungen vergleichend dargestellt. Mitt. aus der Zool. Sammlung des Mus. für Naturk. in Berlin, Bd. I, Heft 3, pp. 107–222.

The bird habitats of the Bismarck Archipelago are discussed. This is the earliest detailed study of bird habitats known to the writer.

1901. Das Leben der Ameisen im Bismarck-Archipel, nach eigenen Beobachtungen vergleichend dargestellt. Mitt. aus. d. Zoöl. Mus. in Berlin, Bd. II, Heft 1, pp. 1–69.

An ecological study of ants, their nesting habitats, keys to their ecological relations, and quantitative data.

1902. Stufenfänge echter Spinnen am Riesengebirge. (Eine vergleichend ethologische Studie.) Sitz.-Ber. Ges. naturf. Freunde zu Berlin, 1902, pp. 185–203.
A comparative study of the habitats of spiders.

1903. Winke für ein wissenschaftliches Sammeln von Thieren. Sitzungs-Ber. der Gesell. naturfor. Freunde zu Berlin, 1903, pp. 444–475.
Gives a classification of animal habitats, associations, and a brief history of their recognition by zoölogists. Compare the habitats with those given by Shelford, Physiological Animal Geography, 1911.

1893. Untersuchungen über die Thierwelt der Unterelbe. Sechster Ber. Komm. zur Wissenschaft. Untersuch. der deutschen Meere in Kiel, Jahrg. XVII–XXI, Heft III, pp. 151–185. Berlin.
Lists the fauna of the brackish waters of the lower Elbe River, discusses their relation to the environment (salinity, etc.) and gives quantitative determinations of its frequency per square meter, as determined by digging at low tide.

Meyer, H. A., and Möbius, K.

1865. Fauna der Kieler Bucht. Bd. I. Leipzig.
Not seen by writer.

Locard, A.

1881. De L'Habitat des Mollusques. pp. 88–128. Études sur les Variations Malacologiques d'aprés la Faune Vivante et Fossile de la Partie Centrale du Bassin du Rhone. Tome II, Paris et Lyon.
This is the most detailed study and classification of the habitats of mollusks of land and fresh-water which the writer has seen. It seems to be little known to students. The volume contains many ecological observations. The classification of habitats is often very artificial. See Von Marten's comment (Zoöl. Record for 1881, Vol. XVIII, p. 18, Moll.), which refers to English and German works along similar

Fig. 6. — Remnant of the (original) prairie animal habitat in central Illinois. Loxa, Illinois. These areas are becoming extinct rapidly. Photo. by T. L. Hankinson.

lines, but these have not been found by the writer.

KING, L. A. L., and RUSSELL, E. S.
1909. A Method for the Study of the Animal Ecology of the Shore. Proc. Roy. Phys. Soc. of Edinburgh, Vol. XVII, pp. 225–253.
An associational study of shore animals.

ORTMANN, A. E.
1896. Grundzüge der marinen Tiergeographie. pp. 96. Jena.
Contains much of ecological value.

ENDERLEIN, G.
1908. Biologisch-faunistische Moor- und Dünen-Studien. Ein Beitrag zur Kenntnis-biosynöcischer Regionen in Westprussen. 30 Ber. des Westpreussischen Bot.-Zool. Vereins Danzig. pp. 54–238.
Adopts Dahl's (1903) classification of habitats.

HÖPPNER, H.
1901. Die Bienenfauna der Dünen und Weserabhänge zwischen Uesen und Baden. Beitr. nordwestdeutsch. Volks- und Landesk. her. vom Naturwissen. Ver. zu Bremen, Bd. XV, pp. 231–255.

PIERCE, W. D.
1904. Some Hypermetamorphic Beetles and Their Hymenopterous Hosts. Univ. of Nebraska Studies, Vol. IV, No. 2, pp. 153–190.
This gives a description of the bee community of *Epinomia triangulifera* Vachal, a list of insects in it and valuable data on their parasitic interrelations.

VESTAL, A. G.
1913. An Associational Study of Illinois Sand Prairies. Bull. Ill. State Lab. Nat. His., Vol. X, pp.

STENROOS, K. E.
1898. Das Thierleben im Nurmijärvi-See. Eine Faunis-

tisch-Biologische Studie. Acta Soc. Pro Fauna et Flora Fennica, Vol. XVII, pp. 1–259.
A descriptive associational study of a lake fauna, correlating the fauna and the vegetation.

FORBES, S. A., and RICHARDSON, R. E.
1909. The Fishes of Illinois. Ill. State Nat. Hist. Surv., Vol. III. pp. 357.
Contains numerous observations on the habitats and associations of fish; a subject hitherto greatly neglected.

WESENBERG-LUND, C.
1908. Plankton Investigations of the Danish Lakes. Danish Freshwater Biol. Lab., Op. 5, Part I, pp. 389. Part II, Copenhagen.
The only fresh-water plankton study known to the writer, which takes up the plankton from a distinctly modern ecological standpoint. An excellent summary of the problems of the fresh-water lake plankton. Abundant references to the literature.

ALLEE, W. C.
1912. Seasonal Succession in Old Forest Ponds. Trans. Ill. Acad. Sci., 1911, Vol. IV, pp. 126–131.
To determine the complete composition of an animal association observations must cover all seasons of the year. This paper and the following ones will indicate the general character of the seasonal changes.

WOOD, J. G. and T.
1886. The Field Naturalist's Handbook. pp. 167. Fourth Edition. London.
This is a British work. It gives by months the seasonal succession of moths, butterflies, birds, flowering of plants, notes on habitat, etc.

FRITSCH, C.
1850. Resultate dreijähriger Beobachtungen über die jährliche Vertheilung der Papilioniden. Sitzungsber.

der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1850, Bd. V, pp. 426–433.

1851. Ueber die jährliche Vertheilung der Käfer. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wisssensch. zu Wien, Jahresganges 1851, Bd. VI, pp. 3–42.

1851. Resultate zweijähriger Beobachtungen über die jährliche Vertheilung der Käfer. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1851, Bd. VII, pp. 689–710.

1852. Jährliche Vertheilung der Hemipteren. Sitzungsber. der math.-naturw. Classe der K. Akad. der Wissensch. zu Wien, Jahresganges 1852, Bd. IX, pp. 554–555.

A series of papers showing the seasonal succession in insects at Prague, Bohemia.

a. The Relation of Animals to Pollination and to Plant Galls

The relation of animals to the pollination of plants and to plant galls is a phase of the *associational relation* of organisms, but it has rarely been considered (if at all) from the standpoint of a *biotic community*. The following list will probably aid one but little in gaining this general conception, but once the student has it he will find the list of much assistance. Undoubtedly a relatively new and fertile field for investigation would be to study the interrelations of plants and their pollinators as an ecological community, the association being taken as a unit rather than the individual species of plants or animals.

Bouvier, E. L.

1905. Bees and Flowers. Smithsonian Report for 1904, pp. 469–484. No. 1627.

Knuth, P. (Appel, O., and Loew, E.)

1898–1899. Handbuch der Blütenbiologie. Unter Zugrundelegung von Hermann Müller's Werk: "Die Befruchtung der Blumen durch Insekten." Bd. I. Einleitung

und Litteratur. 1898. Leipzig. Bd. II. Die bisher in Europa und im Arktischen Gebiet gemachten Blütenbiologischen Beobachtungen. Theil 1 und 2. 1899. Leipzig.

Appel, O., and Loew, E.

1904–1905. (Continues Knuth.) Bd. III. Die bisher in Aussereuropäischen Gebieten gemachten Blütenbiologischen Beobachtungen. Thiel 1, 1904–1905, Leipzig; Thiel 2, 1905, Leipzig.

This is an encyclopedia on the relation of animals to the pollination of flowers. Plants are arranged systematically and the visitors are listed. In Bd. II, Th. 2, pp. 559–672, and Bd. III, Th. 2, pp. 259–470, are given systematic-alphabetic lists of animal visitors to flowers. Full references.

Müller, H. (Trans. by D. W. Thompson.)

1883. The Fertilization of Flowers. pp. 669. London.

Needham, J. G.

1900. The Fruiting of the Blue Flag (Iris versicolor L.). Amer. Nat., Vol. XXXIV, pp. 361–386.

Riley, C. V.

1892. The Yucca Moth and Yucca Pollination. Third Ann. Rep. Mo. Bot. Garden, pp. 99–158.

Robertson, C.

1897. Flowers and Insects. Contributions to an Account of the Ecological Relations of the Entomophilous Flora and the Anthophilous Insect Fauna of the Neighborhood of Carlinville, Illinois. Trans. Acad. Sci. St. Louis, Vol. VII, pp. 151–179.

This is only one of a very extensive series of papers published in the Transactions of the St. Louis Academy, Vols. V, VI, VII, and in the Botanical Gazette — beginning with Vol. XIV, 1889, and extending to Vol. XXVIII, 1899.

Trelease, W.

1893. Further Studies of Yuccas and their Pollination.

Fourth Annual Rep. Mo. Bot. Garden, pp. 181–226.

Beutenmüller, W.

1904. The Insect-Galls of the Vicinity of N. Y. City. Am. Mus. Jour., Vol. IV, pp. 89–124.

A descriptive illustrated catalogue. Beutenmüller has published several important papers on galls in the Bull. Amer. Mus. Nat. History.

Adler, H. (Trans. by C. R. Straton.)

1894. Alternating Generations. A Bibliogical Study of Oak Galls and Gall Flies. pp. 198. Oxford.

Cook, M. T.

1905. The Insect Galls of Indiana. Twenty-ninth Ann. Rep. Dept. Geol. and Natural Resources of Indiana, 1904, pp. 801–867.

Descriptive illustrated catalogue.

Houard, C.

1908–1909. Les Zoocécidies des Plantes d'Europe et du Bassin de la Méditerranée. Tome I, pp. 569; II, pp. 573–1247. Paris.

Kirchner, O. von.

1911. Blumen und Insekten, ihre Anpassungen aneinander und ihre Gegenseitige Abhängigkeit. pp. 436. Leipzig.

Küster, E.

1911. Die Gallen der Pflanzen. Ein Lehrbuch für Botaniker und Entomologen. pp. 437. Leipzig.

Ross, H.

1911. Die Pflanzengallen (Cecidien) Mittel- und Nord Europas ihre Erreger und Biologie und Bestimmungstabellen. pp. 350. Jena.

b. Subterranean and Cave Associations

Banta, A. M.

1907. The Fauna of Mayfield's Cave. Carnegie Inst. Pub. No. 67. pp. 114.

The cave environment, the vital optimum, and the food relations are discussed. A valuable paper.

BLATCHLEY, W. S.

1896. Indiana Caves and their Fauna. Twenty-first Ann. Rep. Geol. and Natural Resources of Indiana, pp. 121–212.

DENDY, A.

1896. The Cryptozoic Fauna of Australasia. Austr. Assoc. Adv. Sci., 1895, pp. [1–21].

On animals living under stones, logs, and bark of trees.

DIEM, K.

1903. Untersuchungen über die Bodenfauna in den Alpen. Jahrb. d. St. Gallischen Naturwiss. Gesellsch. f. 1901–1902, pp. 234–414.

HAMANN, O.

1896. Europäische Höhlenfauna. Eine Darstellung der in den Höhlen Europas lebenden Tierwelt mit besonderer Berücksichtigung der Höhlenfauna Krains. pp. 296. Jena.

MOTTER, M. G.

1898. A Contribution to the Study of the Fauna of the Grave. A Study of One Hundred and Fifty Disinterments, with Some Additional Experimental Observations. Jour. N. Y. Ent. Soc., Vol. VI, pp. 201–231.

A list of invertebrates, snails, crustacea, insects, etc., found in graves. Table compiled from Megnin shows the kinds of animals which invade bodies at the different stages of decay. This is a form of succession comparable to the changes in the animals living in a log at different stages of decay.

PACKARD, A. S.

1888. The Cave Fauna of North America, with Remarks on the Anatomy of the Brain and Origin of the Blind Species. Memoirs Nat. Acad. Sci., Vol. IV, pp. 1–156.

Monographic treatment; extensive references to literature.

Scott, W.

1909. An Ecological Study of the Plankton of Shawnee Cave. With Notes on the Cave Environment. Biol. Bull., Vol. XVII, pp. 386–406.

c. Selected References on Aggregations and Associations

Adams, Chas. C.

1909. The Coleoptera of Isle Royale, Lake Superior, and their Relation to the North American Centers of Dispersal. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 157–215.

On pp. 159–163 the habitats and succession of beetles are briefly discussed.

1909. Notes on Isle Royale Mammals and their Ecological Relations. *Ibid.*, pp. 389–422.

Brief mention of mammal associations and successions, pp. 390–393.

Antipa, G.

1912. Die Biologie des Inundationsgebietes der unteren Donau und des Donaudeltas. Verhand. VIII. Inter. Zoöl.-Kongresses zu Graz, 1910, pp.163–208.

Description of the biological conditions on the flooded lower Danube and its delta.

Baker, H. B.

1911. Mollusca. pp. 121–176. In A Biological Survey of the Sand Dune Region on the South Shore of Saginaw Bay, Michigan. Ann. Rep. Mich. Board of Geol. and Biol. Survey for 1910. Lansing.

Rather full notes on mollusca, grouped by habitats.

Chapman, F. M.

1909. The Habitat Groups of North American Birds in the American Museum of Natural History. Am. Mus. Nat. His., Guide Leaflet No. 28. pp. 48.

A descriptive illustrated account of the remarkable

habitat exhibits in the museum. The most remarkable series of its kind in existence. An excellent example of the educational value of ecological ideas.

Dahl, F.

1896. Vergleichende Untersuchungen über die Lebensweise wirbelloser Aasfresser. Sitzungsber. d. K. Akad. Wissen. Berlin, 1896. I, pp. 17–30.

A study of carrion-feeding insects by the trapping method. The kinds of insects attracted change with the stage of decay. There is thus a succession. Compare with Moffat's studies (1898).

Gates, F. C.

1911. Summer-bird Life in the Vicinity of Havana, Illinois, in its Relation to the Prominent Plant Associations. Wilson Bulletin, Vol. XXIII, No. 74, pp. 1–27.

One of the relatively few associational studies of birds.

Girod, P.

1891. Les Sociétés chez les Animaux. pp. 342. Paris.

Gleason, H. A.

1909. The Ecological Relations of the Invertebrate Fauna of Isle Royale, Michigan. Ann. Rep. Mich. Geo. Surv. for 1908, pp. 57–78.

Grabau, A. U.

1898. Zoölogy: Marine Invertebrates. pp. 67–96. Grabau, A. W., and Woodman, J. E. (editors). Guide to Localities Illustrating the Geology, Marine Zoölogy, and Botany of the Vicinity of Boston. Salem, Mass.

Hart, C. A., and Gleason, H. A.

1907. On the Biology of the Sand Areas of Illinois. Bull. Ill. State Lab. Nat. Hist., Vol. VII, pp. 137–272.

Insect associations are discussed on pp. 220–227. Habitats are figured, and associated plants and animals are listed.

FIG. 7. — A deciduous forest (original) as an animal habitat. The Brownfield woods, Urbana, Illinois. Photo. by H. C. Chenoweth.

HANKINSON, T. L.

1910. Ecological Notes on the Fishes of Walnut Lake, Michigan. Trans. Amer. Fisheries Soc., 1910, pp. 195–206.

One of the few papers dealing with the fish associations in a lake.

1910. An Ecological Study of the Fish of a Small Stream. Trans. Ill. State Acad. Sci., Vol. III, pp. 23–31.

HERMS, W. B.

1907. An Ecological and Experimental Study of Sarcophagidæ with Relation to Lake Beach Débris. Jour. Exper. Zoöl., Vol. IV, pp. 45–83.

JORDAN, H.

1883. Die Binnenmollusken der nördlich gemässigten Länder von Europa und Asien und der Arktischen Länder. Nova Acta der Ksl. Leop.-Carol.-Deutschen Akad. der Naturf., Bd. XLV, Nr. 4, pp. 181–402. Halle.

On pp. 201–253 there are many observations on molluskan ecology, including habitats, table of habitats of freshwater mollusks, and important observations on habitat variations or forms. Most of the paper is devoted to geographic problems.

KOFOID, C. A.

1903. The Plankton of the Illinois River, 1894–1899, with Introductory Notes upon the Hydrography of the Illinois River and its Basin. Part I, Bull. Ill. State Lab. Nat. Hist., Vol. VI, pp. 95–629.

The results of a prolonged, detailed study of the Illinois River plankton; capable of an associational interpretation.

LINTNER, J. A.

1878. Report on the Insects and Other Animal Forms of Caledonia Creek, New York. Tenth Ann. Rep. N. Y. Fishery Comm. for 1877, pp. 12–36.

One of the relatively few studies of the animals of a

small stream; a census rather than an ecological study.

McCreary, O.
1909. The Ecological Distribution of the Birds of Isle Royale, Lake Superior. Ann. Rep. Mich. Geol. Surv. for 1908, pp. 81–95.
Habitat preferences of birds.

Morse, A. P.
1904. Researches on North American Acridiidæ. Carnegie Inst., Pub. 18. pp. 55.
Associational groupings of the short-horned grasshoppers, with figures of habitats.

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COLLEGE ZOÖLOGY

By

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Illustrated, Cloth, 12mo, xxiv + 733 pp., $2.60 net

This book is intended to serve as a text for beginning students in universities and colleges, or for students who have already taken a course in general biology and wish to gain a more comprehensive view of the animal kingdom. It differs from many of the college text-books of zoölogy now on the market in several important respects: (1) the animals and their organs are not only described, but their functions are pointed out; (2) the animals described are in most cases native species; and (3) the relations of the animals to man are emphasized. Besides serving as a text-book, it is believed that this book will be of interest to the general reader, since it gives a bird's-eye view of the entire animal kingdom as we know it at the present time.

Within the past decade there has been a tendency for teachers of zoölogy to pay less attention to morphology and more to physiology. As a prominent morphologist recently said, "Morphology . . . is no longer in favor . . . and among a section of the zoölogical world has almost fallen into disgrace" (Bourne). The study of the form and structure of animals is, however, of fundamental importance, and is absolutely necessary before physiological processes can be fully understood; but a course which is built up on the "old-fashioned morphological lines" is no longer adequate for the presentation of zoölogical principles.

The present volume has not been made by merely adding a description of the vertebrates to the author's "Introduction to Zoölogy" (for a brief account of which see the last pages of this circular). On the contrary, it is a new work throughout, although the same general method of treatment, which proved so successful in the earlier book, has been employed in this one. Similarly, in the preparation of this book the author has submitted the manuscript of each chapter to a scholar and teacher of unquestioned authority in the particular field. The criticisms and suggestions thus secured have greatly increased both the accuracy and the practicability of the text.
